Program Analysis Methodology

Office of Transportation Technologies

Quality Metrics 2000
- Final Report -

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Prepared by:

OTT Analytic Team
http://www.ott.doe.gov/facts.html

Science Communications Planning

John D. Maples

James S. Moore, Jr.

Philip D. Patterson

Vincent D. Schaper

Prepared for:

U.S. Department of Energy
Office of Transportation Technologies
Washington, D.C.

Foreword

The Analytic Support Team for the Office of Transportation Technologies, which is responsible for this report, consists of: Phil Patterson of the Office of Transportation Technologies in the U.S. Department of Energy, John Maples of TRANCON, Inc. (subcontractor to Oak Ridge National Laboratory), Jim Moore of TA Engineering, Inc. (subcontractor to Argonne National Laboratory), and Vince Schaper of the National Renewable Energy Laboratory.

This report reflects the efforts of many program staff persons and researchers of the U.S. Department of Energy, the national scientific research laboratories, and related contractors. An attempt is made here to acknowledge the efforts of individuals with significant levels of involvement.

Strategic direction, critical review comments and a variety of technical analytical inputs were provided by Phil Patterson. A significant portion of the technical analyses and results generated are due to the efforts of the Analytic Support Team. A special acknowledgement is offered for the work of John Maples, who serves as the capable, creative and responsive lead analyst for the Quality Metrics vehicle choice modeling and other OTT program analysis efforts. Vince Schaper had lead responsibility for carbon impact analyses and economic impact assessments.

Numerous other individuals and organizations assisted this project in a range of capacities. Anant Vyas has provided enhanced and expanded life-cycle cost tools and results as presented in Section 5. Other research and analytical personnel in the Argonne National Laboratory Center for Transportation Research who provided assistance and technical insight include Dan Santini, Marianne Mintz and Michael Wang. Stacy Davis of Oak Ridge National Laboratory provided Truck Inventory and Use Survey results. Melanie Bennett of TA Engineering, once again effectively coordinated inputs from the many contributors, and continues to provide timely assistance in producing this document.

The continuing efforts of the OTT management and program staff in providing needed technology characterizations and program information also are recognized.

In my role as contributing analyst and lead author for this report, I wish to express my appreciation for the help of all contributors.

Jim Moore
TA Engineering, Inc.

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1.0 Introduction

"Quality Metrics" evaluations are conducted on an annual basis in the U.S. DOE Office of Energy Efficiency and Renewable Energy (EE/RE) to assess the energy and environmental benefits potential of EE/RE programs. The Quality Metrics program of EE/RE and the preparation of the EPACT 2021 report to Congress led to the development of an impacts assessment methodology for the Office of Transportation Technologies (OTT), which is continually improved and updated. This document provides the ***final documentation for the Quality Metrics 2000 (QM 2000)*** analytical process and results, and an overview discussion of continuing work. It is named QM ***2000*** because the benefits are listed in the FY***2000*** budget to Congress.

The analytic impacts methodology is referred to as "OTT Impacts." The scope of the OTT Impacts Assessments contains analyses that supplement those required by QM. These include

- Comprehensive end-use criteria and carbon pollutant reductions (QM requires carbon as a CO_2 equivalent, hydrocarbon, CO, and NO_x reduction benefits only);
  - OTT Impacts consider the fuel cycle carbon savings (QM benefits are limited to the end-use, fuel economy benefits);
- Gross Domestic Product/Jobs (in the QM process, macroeconomic effects are determined by others);
- Benefit to cost ratio;
- Cost analyses, including the capital/infrastructure estimates, and oil security cost valuations; and
- The determination of benefit to cost ratios.

A significant number of analysis cases and scenarios are formulated in executing the OTT Impacts methodology. Impacts estimates are needed to accompany each budget submission, with final estimates prepared toward the end of the calendar year.

Readers are also referred to recent reports on other related OTT Analytic Initiatives. These include:

- Report by the Energy Information Administration on the effects on refineries and fuel quality of significant "dieselization" of the light vehicle fleet. (Ref. 1)
- A paper on transition paths and scenario's for long-term (year 2050) sustainable transportation fuel supply (Ref. 2).

OTT also has continued to evaluate consumer attitudes, and alternative fuels program strategy options.

The results of many DOE OTT analytical efforts are available on the internet. The website address is http://www.ott.doe.gov/facts.html.

The QM methodology was applied to five “Planning Units” which reflect benefits due to some of the technologies fostered by the four offices in OTT.* The Planning Units are as indicated below:

1) Technology Utilization: CNG, EPACT, and Clean Cities Fleet Mandates
2) Fuels Development: Ethanol used in flexible-fuel vehicles, dedicated vehicles, and fuel cell vehicles; and as contained in blends and extenders.
3) Advanced Automotive Technologies (Light Vehicles and Class 1 and 2 Trucks):
    - Electric Battery Vehicle R&D, including Zero Emission Vehicle (ZEV) mandates
    - Fuel Cell R&D: Gasoline vehicles with 2.1 times conventional vehicle fuel economy
    - Hybrid Vehicle R&D: Gasoline fueled, with 1.4 to 1.65 (depending on vehicle category) times conventional vehicle fuel economy
    - Light Vehicle Engine R&D: Advanced diesel vehicle with 1.35 to 1.4 (depending on vehicle category) times conventional vehicle fuel economy.
4) Heavy Vehicle Technologies Truck (Classes 3 – 8)
5) Advanced Materials:
    - Propulsion System Materials: Ceramics
    - Light Vehicle Materials for electric, hybrid, and fuel cell vehicles
    - Heavy Vehicle Materials.

It is assumed that the electric, hybrid, and fuel cell vehicle technologies will require the use of light vehicle materials to achieve program goals for fuel efficiency.

Given the Quality Metrics targets for expected fuel economy improvement and estimated powerplant efficiency, vehicle weight reductions required to meet fuel economy goals were estimated (Ref. 3). It is assumed that for each ten percent (10%) reduction in vehicle weight, a 6.6% increase in vehicle fuel economy is achieved. Results indicate that advanced materials, defined as the percent of overall fuel economy improvement, account for the following fuel economy benefits:

- Electric Vehicles: 13.2%
- Hybrid Vehicles: 6.6%
- Fuel Cell Vehicles: 16.5%

Prior Quality Metrics (QM 99) analyses and results are described in Reference 4. The Analytic Team has continued to improve the modeling process. For QM 2000, the number of vehicle classes was expanded from four (4) to five (5):

* The four offices are 1) Office of Fuels Development, 2) Office of Advanced Automotive Technologies, 3)Office of Heavy Vehicle Technologies, and 4) Office of Technology Utilization

1) Large Cars (EPA size classes large and midsize);
2) Small Cars (all other car classes);
3) Sport Utility Vehicles;
4) Minivans; and
5) Pickup trucks and large vans.

Compared to prior QM evaluations, the “Passenger Truck” class was separated into “Sport Utility Vehicles” and “Minivans.” This change was implemented to reflect differences in consumer buying preferences between these segments.

Continued attention is given to the medium and heavy vehicle segments. Hybrid electric technology was added to the medium truck sector.

The OTT seeks to develop and promote advanced highway transportation vehicles, systems and alternative fuel use technologies that lead to reduced imported oil, lower regulated emissions and reduced creation of atmospheric gases that may add to the greenhouse effect. To these ends, OTT develops partnerships with elements of the domestic transportation industry, private and public research and development organizations.

All OTT functions and projects are subdivided among four (4) functional offices, as indicated in Exhibit 1-1.

- **The Office of Fuels Development** strives to increase the use of biologically-derived fuels in highway vehicle applications.

- **The Office of Advanced Automotive** develops advanced technologies for automobiles and other light duty vehicles including electric and hybrid technologies, advanced heat engines, alternative fuels utilization, and advanced high strength/lightweight materials.

- **The Office of Heavy Vehicle Technologies** works on technologies applied to heavy duty trucks and buses, and other large highway vehicles.

- **The Office of Technology Utilization** works to develop and promote user acceptance of advanced transportation technologies and alternative fuels within the US highway vehicle transportation sector.

The relationship between the various OTT Program Elements and the Quality Metrics Planning Units is shown in Exhibit 1-2 below.

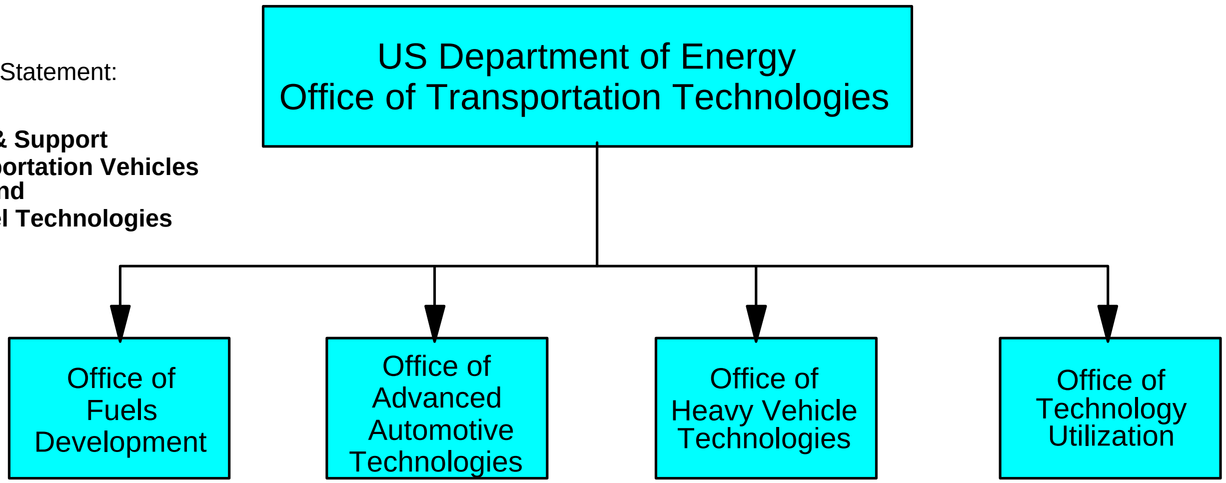
The Quality Metrics and OTT Impacts Analyses are conducted using the Reference Case projections of the Energy Information Administration to define the world energy market characteristics, U.S. energy consumption by economic sector and energy prices. The reader is referred to Publication DOE/EIA-0383 (98), “Annual Energy Outlook 1998, With Projections

Through 2020." The current version of this report is available at the following website address: http://www.eia.doe.gov/oiaf/aeo98/homepage.html.

Exhibit 1-1. OTT Organization

Short Mission Statement:

Develop & Support
Advanced Transportation Vehicles
and
Alternative Fuel Technologies



	Office of Fuels Development	Office of Advanced Automotive Technologies	Office of Heavy Vehicle Technologies	Office of Technology Utilization
Transportation & Related Technologies	Biofuels Systhesis Wood Cropping Herbacious Cropping Ehanol Conversion Bio-Diesel	Hybrid Vehicles Electric Vehicles Heat Engines Fuel Cells Batteries Alternative Fuel Vehicles	Engine Technologies Vehicle Systems Technologies Fuels and Lubrication Technologies	Automobiles & Light Trucks, Heavy Trucks & Transit Buses
Programs	Regional Biomass Pgm Ethanol Biomass Pgm Biofuels Information Center Biofuels Information Network	PNGV:Partnership For A New Generation Vehicle CARAT EV America GATE	Heavy Vehicle Emissions Program Alternative Fuel Truch Application Program	Clean Cities Program EPAct Alternative Fuels Requirements Program Fleet Test Operations Alternative Fuels Data Center
Principle Science Disciplines	Combustion, Fuel Systhesis	Batteries/Electrochemical/ Material/Ceramics-Light weight/High Temp Combustion	Combustion, Mechanical Systems,Tribology, Chemical	Testing, fleet test management, data analysis

Source: DOE OTT Website: http://www.ott.doe.gov/doeorgch.html

Exhibit 1-2: Relationship Between Quality Metrics and OTT Program

Planning Unit	Related OTT Programs
Technology Utilization	Clean Cities Testing and Evaluation Energy Policy Act Replacement Fuels Program Advanced Vehicle Competitions
Fuels Development	Biofuels a) Ethanol Production b) Biodiesel Production c) Feedstock Production d) Regional Biomass Energy Program Fuels Utilization a) Advanced Petroleum Based Fuels b) Alternative Fuels • Fueling Infrastructure
Advanced Automotive Technologies	Hybrid Systems R&D a) Light Vehicles Propulsion & Ancillary Sys. b) High Power Energy Storage c) Advanced Power Electronics Fell Cell R&D a) Systems b) Components c) Fuel Processor Electric Vehicle R&D a) Advanced Battery Development b) Exploratory Research Advanced Combustion Engine a) Hybrid Direct Injection Engine b) Combustion and Aftertreatment R&D Cooperative Automotive Research For Advanced Technologies
Heavy Vehicle Technologies	Hybrid Systems R&D Advanced Combustion Engine R&D Materials Technologies
Advanced Materials	Propulsion Materials Technologies Lightweight Materials Technologies High Temperature Materials Laboratory

Analysis results quantify benefits including energy and petroleum reductions, carbon equivalent greenhouse gas emissions, criteria pollutant emissions reductions, and the associated economic impacts on the Gross Domestic Product (GDP) and jobs. Life-cycle cost analyses also are in progress to define advanced technology economic performance compared to conventional technology estimates. Battery electric vehicle technology has been emphasized in efforts to date.

This report consists of six principal sections. An overview of the technical analysis process is described in Section 2. Section 3 contains a description of the vehicle choice analysis simulation tools and results. As noted above, the QM 2000 analytical scope includes heavy vehicles, as well as light vehicles. Section 4 discusses the analysis and models used to estimate biomass fuel availability and petroleum reductions. The analysis results and supporting tools used to determine environmental and economic benefits are described in Section 5. The final discussion, Section 6, contains summary observations concerning the analysis process and results, and identifies technical subjects that merit refinement and/or additional consideration in the near future. References follow in Section 7. Where available, website addresses for references are included.

Detailed results of the Quality Metrics analyses are presented in Appendix A. Results contained in this Appendix include:

- QM 2000 benefits summary by Planning Unit (Tables A-1, A-2 and A-3)
- Market Penetration Estimates – percentages and vehicles sold and in use in the fleet (Tables 4-3 to A-9, and A-11)
- Energy benefits – gasoline displaced, biofuels demand, EPACT fuel use, ZEV and EPACT electricity use (Tables A-10, and A-13 to A-16)
- Emissions impacts – carbon, HO_x, CO, and HC reductions in both physical units and dollars (Tables A-17 to A-24), and
- Cost effects – vehicle purchase, aggregate consumer investment, and corporate expenditures (Tables A-25 to A-28).
- Light Vehicle Fuel Economy Projections (Table A-29)
- Medium and Heavy Truck Section Results (Tables A-30 to A-39), and
- GRPA Inputs and Analytical Results (Tables A-40 to A-43)

A discussion of the vehicle choice model used to estimate market penetration of light vehicle technologies is contained in Appendix B. A recent paper on economic impacts of investment in transportation technologies is reproduced as Appendix C. This supplements discussions of economic impacts continued in Section 5.

2.0 Technical Analysis Overview

The analysis process involves the following four activities:

1) Definition of vehicle characteristics for advanced technologies;
2) Market penetration analysis estimated by size class;
3) Energy (petroleum displacement), environmental and economic benefits quantification; and
4) Development of summary documentation.

The time frame for the study spans the present to 2020.

2.1 Advanced Technology Characterizations

The fuel and vehicle characteristics can be considered in three categories: fuel attributes, light vehicle attributes and heavy vehicle attributes. These attributes were defined by program staff, and are subjected to external peer review. The vehicle attributes summaries for the four light vehicle classes are indicated in Exhibits 2-1 through 2-5.

Conventional vehicle attributes are projected to change with time. For example, purchase price is expected to escalate in real terms (See Appendix Table A-25). Flex alcohol vehicles also were considered in the analysis, but these vehicles are assumed to have the same attributes as conventional. The reference year for conventional vehicles attributes is 1996, as the U.S. EPA update for 1997 was not available.

Exhibit 2-1: Technology Characteristics - Large Car (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$23,200	25.7	326	450	1	6.0	131.9
Advanced Diesel	2005 2010	1.07 1.05	1.35 1.35	1.2 1.2	1.0 1.0	1.0 1.0	1.1 1.1	0.8 0.8
Hybrid	2003 2008	1.15 1.05	1.50 2.00	1.2 1.2	1.05 1.05	0.95 0.95	1.0 1.0	0.72 0.72
Fuel Cell	2007 2012	1.20 1.10	2.10 2.10	1.0 1.0	1.05 1.05	0.8 0.8	1.0 1.0	0.72 0.72
Natural Gas	2000 2005	1.105 1.035	1.00 1.00	0.66 0.75	0.9 0.9	0.75 0.75	1.0 1.0	1.0 1.0
SDI	2004 2009	1.05 1.03	1.25 1.25	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0

Exhibit 2-2: Technology Characteristics - Small Car (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$14,800	31.0	372	400	1	7.0	121.1
Advanced Diesel	2003 2008	1.07 1.07	1.35 1.35	1.2 1.2	1.0 1.0	1.0 1.0	1.1 1.1	0.85 0.85
Hybrid	2006 2011	1.1 1.1	1.65 2.0	1.0 1.0	1.05 1.05	0.9 0.9	1.1 1.1	0.77 0.77
Electric	2003 2010	1.5 1.15	4.0 4.0	0.33 0.50	0.6 0.6	0.8 0.8	1.0 1.0	0.73 0.73
SDI	2004 2009	1.05 1.03	1.25 1.25	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0

Exhibit 2-3: Technology Characteristics – Sport Utility Vehicle (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$21,300	21.1	300	450	1.0	7.0	108.3
Advanced Diesel	2004 2009	1.075 1.07	1.45 1.45	1.2 1.2	1.0 1.0	1.0 1.0	1.1 1.1	1.0 1.0
Electric	2004 2010	1.50 1.25	4.0 4.0	0.40 0.58	0.6 0.6	1.0 1.0	1.0 1.0	0.66 0.66
Hybrid	2011 2015	1.12 1.10	1.40 1.75	1.0 1.0	1.05 1.05	1.0 1.0	1.1 1.1	0.75 0.75
Fuel Cell	2013 2020	1.15 1.15	2.1 2.1	1.0 1.0	1.1 1.1	0.8 0.8	1.1 1.1	0.66 0.66
Natural Gas	2002 2002	1.05 1.05	1.0 1.0	0.75 0.75	0.9 0.9	0.75 0.75	1.0 1.0	1.0 1.0
SDI	2004 2009	1.05 1.03	1.25 1.25	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0

Exhibit 2-4: Technology Characteristics - Minivan (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$22,060	22.7	350	450	1	7.0	108.3
Advanced Diesel	2004 2009	1.075 1.07	1.45 1.45	1.2 1.2	1.0 1.0	1.0 1.0	1.1 1.1	1.0 1.0
Electric	2004 2010	1.50 1.25	4.0 4.0	0.40 0.58	0.6 0.6	1.0 1.0	1.0 1.0	0.66 0.66
Hybrid	2011 2015	1.12 1.10	1.40 1.75	1.0 1.0	1.05 1.05	1.0 1.0	1.1 1.1	0.75 0.75
Fuel Cell	2013 2020	1.15 1.15	2.1 2.1	1.0 1.0	1.1 1.1	0.8 0.8	1.1 1.1	0.66 0.66
Natural Gas	2002 2002	1.05 1.05	1.0 1.0	0.75 0.75	0.9 0.9	0.75 0.75	1.0 1.0	1.0 1.0
SDI	2004 2009	1.05 1.03	1.25 1.25	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0

Exhibit 2-5: Technology Characteristics – Pickup Trucks and Large Vans (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$15,000	31.0	350	500	1	7.0	122
Advanced Diesel	2002 2007	1.1 1.07	1.35 1.35	1.2 1.2	1.0 1.0	1.0 1.0	1.1 1.1	1.0 1.0
Natural Gas	2000 2005	1.11 1.05	1.0 1.0	0.9 0.9	0.9 0.9	0.75 0.75	1.0 1.0	1.0 1.0
SDI	2004 2009	1.05 1.03	1.25 1.25	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0

The exhibits show year of technology introduction (intro.) and year of maturity. Technology maturity is determined from program manager input and varies by the complexity of the technologies, as well as goals set forth by the offices.

Years of introduction vary among the car and truck size classes to account for market growth and development. As Exhibits 2-1 through 2-5 indicate, in some cases, technology characteristics also vary among the size classes both for conventional gasoline and alternative technologies.

2.2 Market Penetrations and Benefits Analyses

Market maturity is determined by "S-curves" which reflect consumer acceptance of advanced technologies over a specified period of time (represented in years) beginning after initial market acceptance. Years of introduction and “S-curve” assumptions are indicated in Exhibit 2-6. Although technology commercialization might be specified as year 2005, as shown for hybrid large cars, the vehicle choice model may not estimate market penetration until a later date. The

Vehicle Size/Consumer Choice (VSCC) model adjusts the estimated market penetration by the appropriate correction factor as determined by the length (time period) of the S-curve. Subsequent market penetration estimates are adjusted as time moves along the length of the curve. The incremental advanced vehicle market penetration lost in the S-curve adjustment process is assumed to return to the conventional vehicle.

Exhibit 2-6: Technology Introduction Assumptions

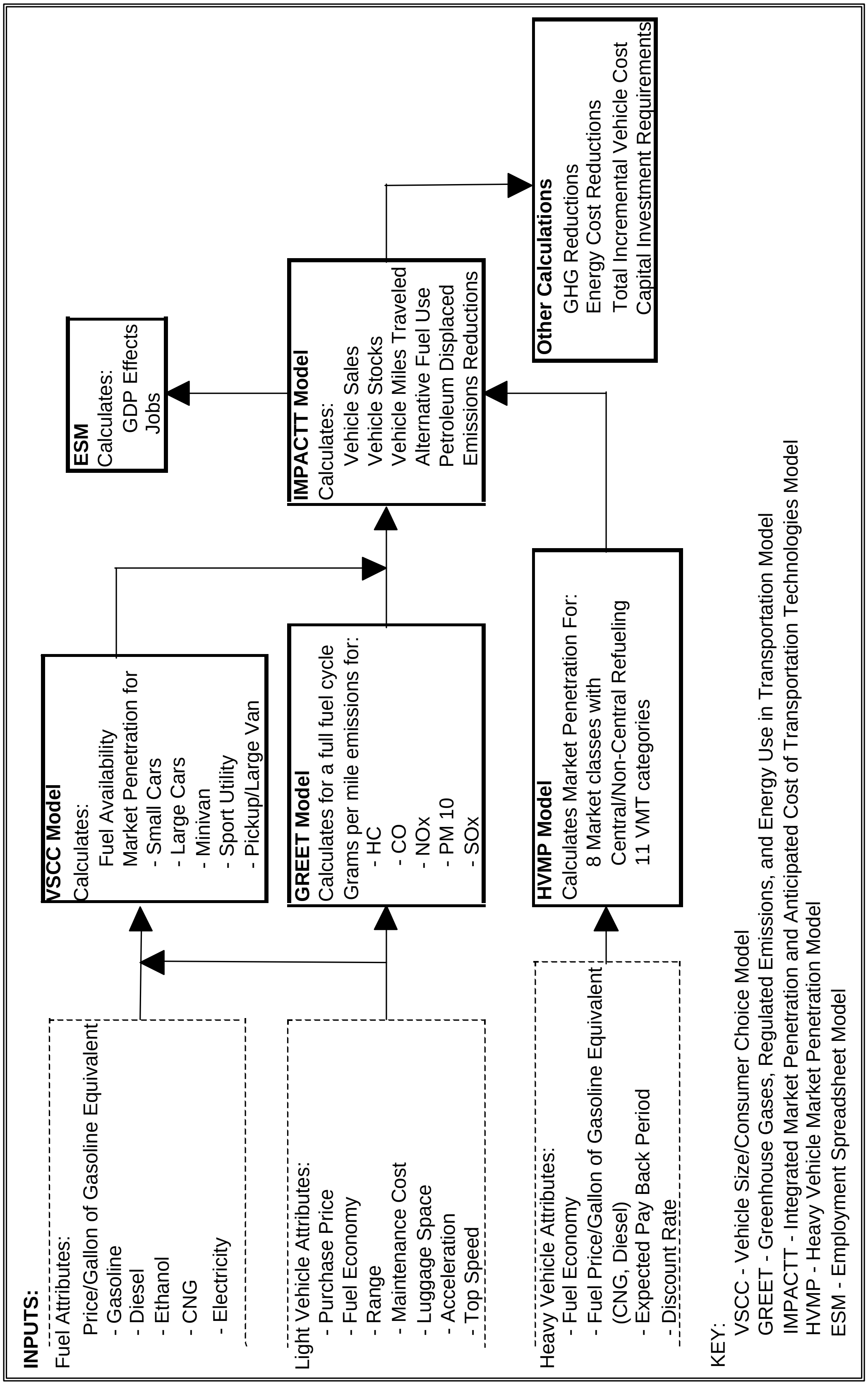
Technology	Small Car		Large Car		Minivan		Sport Utility		Pickup Truck/ Large Van	
	Intro. Year	S-curve	Intro. Year	S-curve	Intro. Year	S-curve	Intro. Year	S-curve	Intro. Year	S-curve
Advanced Diesel	2003	5	2005	5	2004	5	2004	5	2002	5
Direct-Injection Gasoline	2004	5	2004	5	2004	5	2004	5	2004	5
CNG	-	-	2000	5	2002	3	2002	3	2000	5
Electric	2003	5	-	-	2004	6	2004	6	-	-
Hybrid	2006	3	2003	5	2011	4	2011	4	-	-
Fuel Cell	-	-	2007	5	2013	7	2013	7	-	-

The modeling process is indicated in Exhibit 2-7. The vehicle attributes for the advanced technologies are input into the vehicle choice model and emissions models. The light vehicle choice model then estimates market penetration by size class. The emissions model estimates tailpipe and upstream emissions on a grams per mile basis for each technology. For light vehicles, the market penetrations and emissions rates are then input into the Integrated Market Penetration and Anticipated Cost of Transportation Technologies, or IMPACTT, the vehicle stock/energy/emission model. Finally, energy and vehicle stock information is input into the economic model to estimate GDP and jobs impacts.

The heavy vehicle choice model estimates market penetration by market class. For heavy vehicles, the market penetrations are input into IMPACTT, then energy and vehicle stock information is input into the economic model to estimate GDP and jobs impacts.

All models shown in Exhibit 2-7 operate in Microsoft Excel.

Exhibit 2-7: QM Modeling Process



3.0 Vehicle Choice Analysis

Vehicle choice analysis techniques were used to estimate the market penetration of technologies in five light vehicle classes, medium trucks (classes 3 through 6) and heavy trucks (classes 7 & 8).

3.1 Light Vehicles

Vehicle Size/Consumer Choice (VSCC) Model

The Vehicle Size/Consumer Choice (VSCC) model was developed to define the successful introduction of technologies in light vehicles by vehicle size class. This modeling exercise acknowledges that not all technologies are applicable to all size classes and that the introduction of advanced technologies is a gradual one. The VSCC model is a discrete choice, multi-attribute logit model designed to simulate the household market for alternative-fuel light vehicles. The model forecasts, to the year 2020, the future sales of conventional and alternatively fueled light vehicles by size class, technology and fuel type. Market penetration estimates are based on consumer derived utilities related to vehicle attributes that are associated with the different alternative fuels and advanced propulsion technologies. As such, the model is "household" based. Other market sectors are considered in various "off-line" calculations.

The vehicle demand function used in this model is based on the utility-maximization theory in which the consumer demand for alternative vehicles is defined as a function of the attributes of these vehicles and the fuels they use. The total utility of each light vehicle technology and fuel makeup is determined by the sum of the attribute utilities of that vehicle for each size class. The size class market share penetration estimates for the different technologies are a function of each technology's total utility compared to the total utility of other vehicles and technologies in that size class. The technology's total utility is calculated by summing attribute input values that have been multiplied by their corresponding coefficient. A discussion of the model structure, including the vehicle attributes and attribute coefficients considered is presented in Appendix B.

The attributes of conventional and alternative vehicle technologies were defined for five vehicle classes:

- small car
- large car
- minivan
- sport utility vehicle
- pickup and large van.

Technologies considered include:

- Conventional -- spark ignition, gasoline
- Advanced diesel engine – which offers a thirty-five percent (35%) fuel economy improvement with the same tailpipe emissions as conventional vehicles. This emissions

performance assumption is significant, given historical experience that diesel engines pollute more than comparable gasoline-fueled, spark ignition engines.

- Hybrid – grid-independent, parallel or series configuration, using gasoline.
- Fuel cell – proton exchange membrane, fueled with gasoline, ethanol or hydrogen.
- Natural gas – spark ignition-powered vehicle, similar to conventional, but fueled with natural gas (dedicated).
- Direct injection gasoline – spark ignited vehicle with gasoline injected directly into the combustion chamber. This technology also is referred to as spark-ignition direct injection (SDI).

Certain technologies were not considered for some vehicle classes due to various market characteristic assumptions. Electric was not considered as viable in sizeable quantities for the large car. For the small car, natural gas and fuel cell were not considered. Electric, hybrid or fuel cell technologies were not considered for pickup and large van applications. Also, LPG and methanol were not considered in this analysis because: 1) OTT conducts minimal R&D efforts with these fuels; and 2) DOE Policy Office analysis indicates that these fuels would be imported in large amounts if they were used on a large scale in the transportation sector (Ref. 5). As a result, replacing imported petroleum with imported LPG or methanol would not help the U.S. balance of trade.

Of principal concern to the analysis is the alternative vehicle fuel economy, cost, relative range and maintenance cost in comparison to conventional vehicles. Fuel economy ratio assumptions are indicated in Exhibit 3-1. At the initiation of QM 2000 Analyses, fuel cell vehicle relative fuel economy started at 2.1 times conventional and increased to 3.0 at maturity. Based on a peer review of the preliminary work, the relative fuel economy attribute at maturity was reduced to 2.1. For electric vehicles, the values reflect comparisons at the plug and the fuel tanks. The cost ratio case is shown in Exhibit 3-2. Exhibit 3-3 shows the comparison of relative ranges. Exhibit 3-4 shows the comparison of relative maintenance. The entry NIC (not in class) indicates that the technologies were not considered in the designated vehicle size class.

As indicated in Exhibit 3-1, the electric, diesel, hybrid, and direct injection technology vehicles have significantly better fuel economies than conventional vehicles. All technology fuel economy ratios are applicable to the point of use. While the values shown are for end-use, total energy cycle implications also are considered in developing the parameters indicated in Exhibit 3-1.

The cost comparison indicates that the alternative fuel vehicle technologies are consistently more expensive than conventional. When comparing ranges, electric and natural gas-fueled vehicles are found to have significant range penalties. Advanced diesel vehicles, however, had a range benefit due, in part, to the higher volumetric energy content of diesel fuel compared with gasoline.

Exhibit 3-1: Fuel Economy Ratio

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	MINIVAN	SPORT UTILITY VEHICLE	PICKUP & LARGE VAN
ELECTRIC	**INTRO.**	4.00	NIC	4.00	4.00	NIC
	MATURITY	4.00	NIC	4.00	4.00	NIC
ADVANCED DIESEL	**INTRO.**	1.35	1.35	1.45	1.45	1.35
	MATURITY	1.35	1.35	1.45	1.45	1.35
HYBRID	**INTRO.**	1.65	1.50	1.40	1.40	NIC
	MATURITY	2.00	2.00	1.75	1.75	NIC
FUEL CELL	**INTRO.**	NIC	2.10	2.10	2.10	NIC
	MATURITY	NIC	2.10	2.10	2.10	NIC
NATURAL GAS	**INTRO.**	NIC	1.00	1.00	1.00	1.00
	MATURITY	NIC	1.00	1.00	1.00	1.00
DIRECT-INJECTION GASOLINE	**INTRO.**	1.25	1.25	1.25	1.25	1.25
	MATURITY	1.25	1.25	1.25	1.25	1.25

Exhibit 3-2: Cost Ratio

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	MINIVAN	SPORT UTILITY VEHICLE	PICKUP & LARGE VAN
ELECTRIC	**INTRO.**	1.50	NIC	1.50	1.50	NIC
	MATURITY	1.15	NIC	1.25	1.25	NIC
ADVANCED DIESEL	**INTRO.**	1.07	1.07	1.08	1.08	1.10
	MATURITY	1.07	1.05	1.07	1.07	1.07
HYBRID	**INTRO.**	1.10	1.15	1.12	1.12	NIC
	MATURITY	1.10	1.05	1.10	1.00	NIC
FUEL CELL	**INTRO.**	NIC	1.20	1.15	1.15	NIC
	MATURITY	NIC	1.10	1.15	1.15	NIC
NATURAL GAS	**INTRO.**	NIC	1.11	1.05	1.05	1.11
	MATURITY	NIC	1.04	1.05	1.05	1.05
DIRECT-INJECTION GASOLINE	**INTRO.**	1.05	1.05	1.05	1.05	1.05
	MATURITY	1.03	1.03	1.03	1.03	1.03

Note: NIC = Not in Class

Exhibit 3-3: Relative Range Ratio

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	MINIVAN	SPORT UTILITY VEHICLE	PICKUP & LARGE VAN
ELECTRIC	INTRO.	0.33	NIC	0.40	0.40	NIC
	MATURITY	0.50	NIC	0.58	0.58	NIC
ADVANCED DIESEL	INTRO.	1.20	1.20	1.20	1.20	1.20
	MATURITY	1.20	1.20	1.20	1.20	1.20
HYBRID	INTRO.	1.00	1.20	1.00	1.00	NIC
	MATURITY	1.00	1.20	1.00	1.00	NIC
FUEL CELL	INTRO.	NIC	1.00	1.00	1.00	NIC
	MATURITY	NIC	1.00	1.00	1.00	NIC
NATURAL GAS	INTRO.	NIC	0.66	0.75	0.75	0.90
	MATURITY	NIC	0.75	0.75	0.75	0.90
DIRECT-INJECTION GASOLINE	INTRO.	1.00	1.00	1.00	1.00	1.00
	MATURITY	1.00	1.00	1.00	1.00	1.00

Exhibit 3-4: Relative Maintenance

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	MINIVAN	SPORT UTILITY VEHICLE	PICKUP & LARGE VAN
ELECTRIC	INTRO.	0.60	NIC	0.60	0.60	NIC
	MATURITY	0.60	NIC	0.60	0.60	NIC
ADVANCED DIESEL	INTRO.	1.00	1.00	1.00	1.00	1.00
	MATURITY	1.00	1.00	1.00	1.00	1.00
HYBRID	INTRO.	1.05	1.05	1.05	1.05	NIC
	MATURITY	1.05	1.05	1.05	1.05	NIC
FUEL CELL	INTRO.	NIC	1.05	1.10	1.10	NIC
	MATURITY	NIC	1.05	1.10	1.10	NIC
NATURAL GAS	INTRO.	NIC	0.90	0.90	0.90	0.90
	MATURITY	NIC	0.90	0.90	0.90	0.90
DIRECT-INJECTION GASOLINE	INTRO.	1.00	1.00	1.00	1.10	1.00
	MATURITY	1.00	1.00	1.00	1.10	1.00

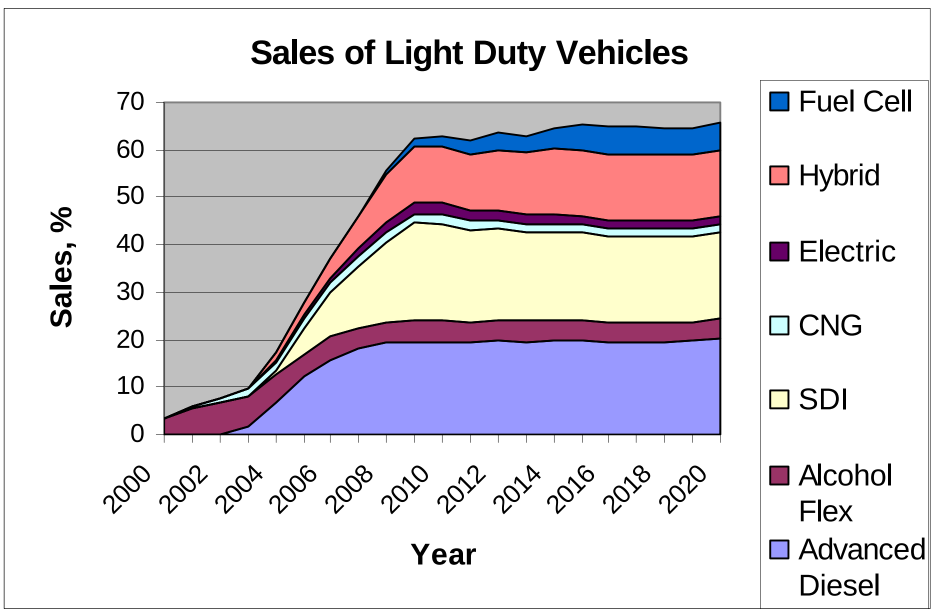
Note: NIC = Not in Class

The overall light vehicle sales penetration forecast is a weighted average of the sales penetration estimates provided by the VSCC Model by size class. Exhibit 3-5 details the sales and stocks of advanced light vehicle technologies in years 2000, 2010, and 2020. The analyses show that at aggressive market penetration rates, advanced technologies will comprise more than half (62.7%) of light vehicle sales by 2010. However, it takes until 2017 for advanced technology vehicles to exceed fifty percent (50%) of the vehicle fleet. (See Appendix A, Table A-8). Exhibit 3-6 is a graph that was developed from the same tabular data as shown in Exhibit 3-5.

Exhibit 3-5: Market Penetration of Alternative Light Vehicles in Sales and Stocks

TECHNOLOGY	YEAR 2000		YEAR 2010		YEAR 2020	
	SALES, %	STOCKS, %	SALES, %	STOCKS, %	SALES, %	STOCKS, %
ADVANCED DIESEL	0.0	0.0	19.5	8.5	20.3	17.7
DIRECT-INJECTION GASOLINE	0.0	0.0	20.2	6.6	18.1	16.9
ALCOHOL FLEX	3.3	0.4	4.6	3.8	4.1	4.0
CNG	0.1	0.0	2.0	1.3	1.6	1.7
HYBRID	0.0	0.0	11.7	3.7	14.0	11.5
ELECTRIC	0.0	0.0	2.5	0.8	1.8	1.9
FUEL CELL	0.0	0.0	2.2	0.4	6.0	3.9
TOTAL	**3.4**	**0.4**	**62.7**	**25.1**	**65.9**	**57.6**

Exhibit 3-6: Market Penetration of Alternative Light Vehicle Sales (Graphical Presentation)



Exhibits 3-7 through 3-11 are graphical representations of the market penetration of each vehicle class. In 2010, advanced diesel vehicles comprise the largest percentage (32%) of alternative small cars. This share is increased to thirty-six percent (36%) by 2020. Hybrid and SDI reach twenty-two percent (22%) and nineteen percent (19%), respectively, in 2010, and reduce slightly by 2020. The scenario for alternative large car penetration indicates that hybrid cars reach twenty-three percent (23%) in 2010, and spark-ignited direct injection (SDI) is at seventeen percent (17%) in 2010, and reduces slightly in 2020. As shown in Exhibit 3-9, none of the advanced technologies penetrate well in the Minivan class. Advanced diesel is the best performer, but never reaches a ten percent (10%) market share.

Exhibit 3-7: Market Penetration of Small Cars

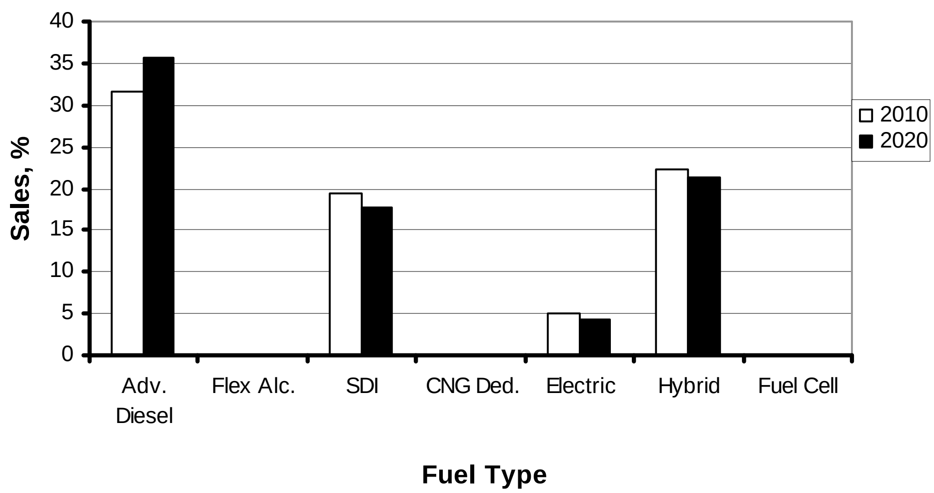


Exhibit 3-8: Market Penetration of Large Cars

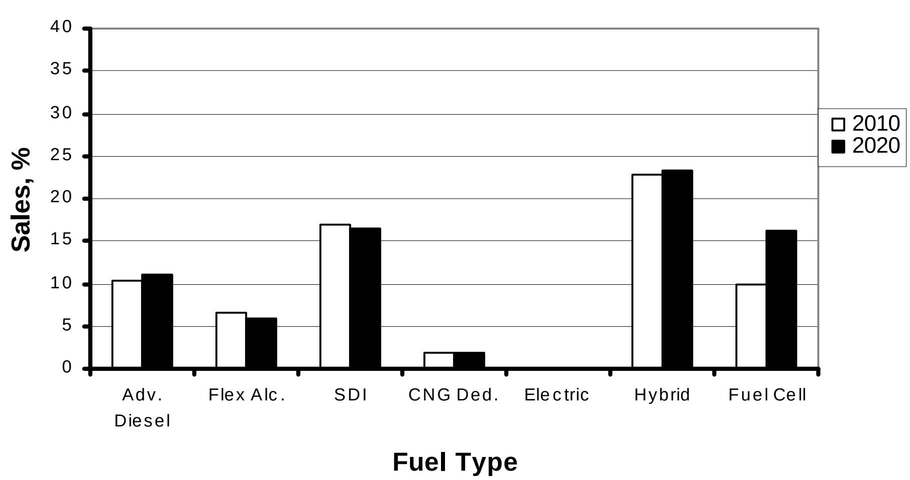


Exhibit 3-9: Market Penetration of Minivans

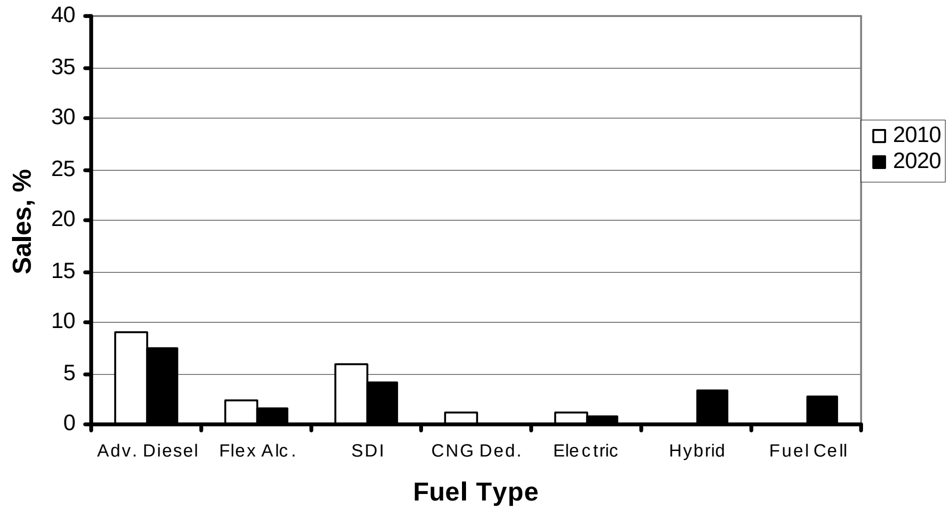
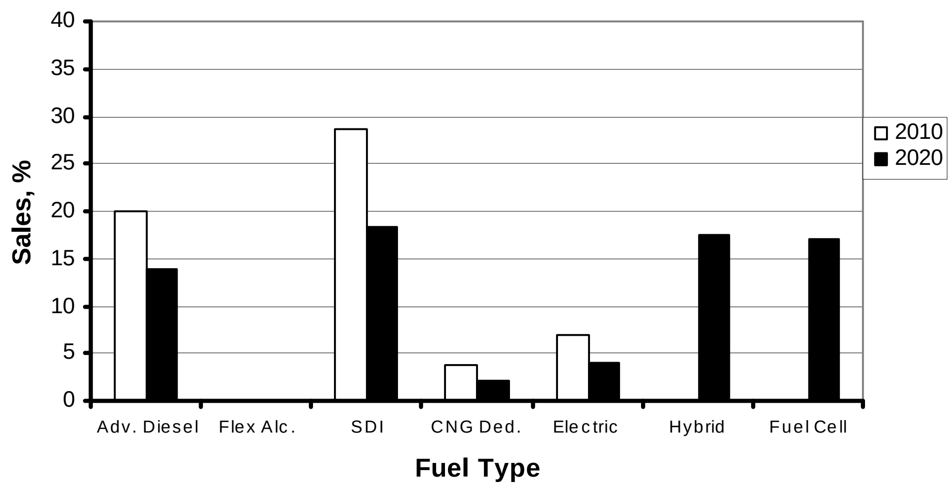


Exhibit 3-10: Market Penetration of Sport Utility Vehicles



Conversely, sport utility buyers are highly receptive to advanced technology, with advanced diesel and SDI performing well in 2010, and advanced diesel, SDI, hybrids, and fuel cells all penetrating to fourteen percent (14%) and higher in 2020.

SDI dominates the pickup and large van market, as indicated in Exhibit 3-11. Advanced diesel and flex alcohol also exceed ten percent (10%) market shares.

Exhibit 3-12 summarizes Exhibits 3-7 through 3-11 for the year 2010. Exhibit 3-13 summarizes the same for the year 2020. Cumulative vehicle "stocks" for each technology also are indicated. For Exhibits 3-7 through 3-11 all technologies are shown on all graphs regardless of whether or not market penetration occurred in that size class. Note that sales are a percent of overall sales for that year, whereas stocks are a percent of the overall vehicle fleet in that year.

Exhibit 3-11: Market Penetration of Pickups & Large Vans

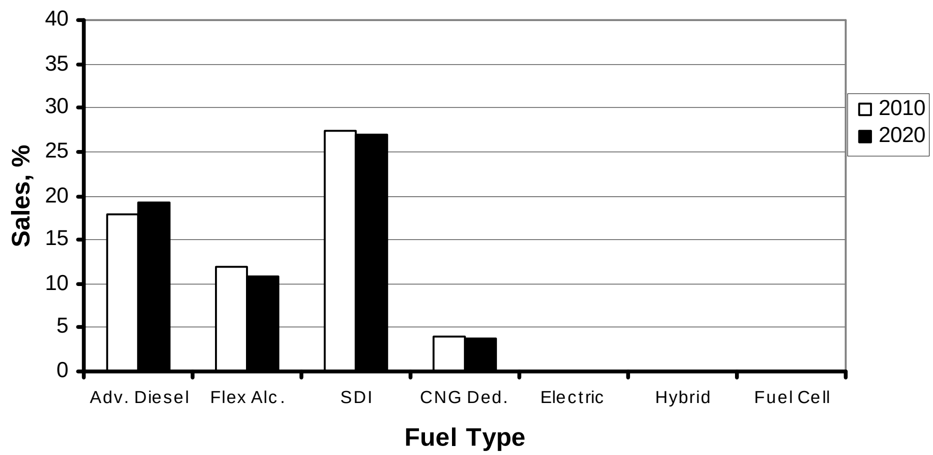


Exhibit 3-12: Penetration of Alternative Light Vehicles in Sales and Stocks, 2010

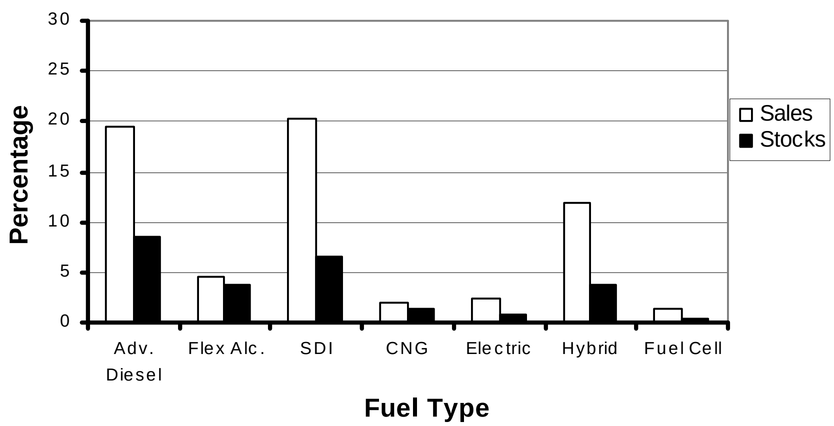
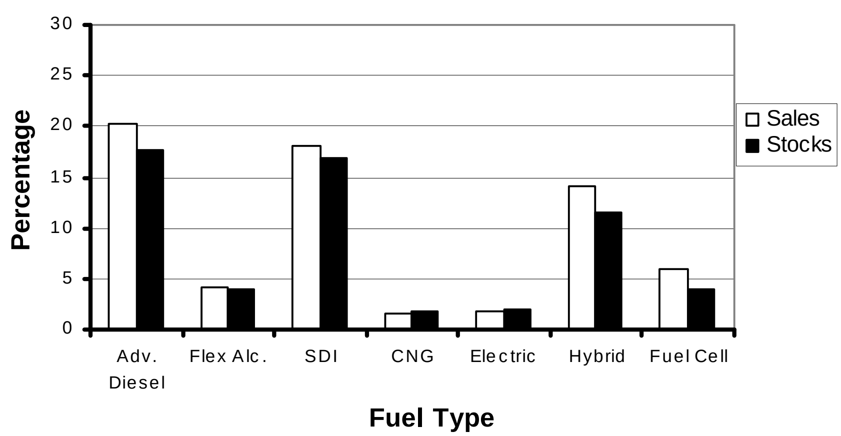


Exhibit 3-13: Penetration of Alternative Light Vehicles in Sales and Stocks, 2020



3.2 Heavy Vehicles

The Heavy Vehicle Market Penetration Model (HVMP) was developed to estimate the potential market impacts of new technologies on the medium and heavy truck market as follows.

- Medium - Classes 3 through 6 and,
- Heavy - Classes 7 and 8 defined as:
  - Type 1 – multi-stop, step van, beverage, utility, winch, crane, wrecker, logging, pipe, garbage collection, dump, and concrete delivery;
  - Type 2 – platform, livestock, auto transport, oil-field, grain, and tank;
  - Type 3 – refrigerated van, drop frame van, open top van, and basic enclosed van.

The HVMP was configured using the 1992 Truck Inventory and Use Survey. Data were examined for all vehicles in use and vehicles two years old or less. The HVMP model utilizes the data constructed from the two years old or less data base. The heavy vehicle market was analyzed to develop market segments with similar operation and use patterns. Refueling and travel characteristics were specifically addressed by vehicle body type and major use classification for the two market segments.

In the medium duty market segment (Classes 3 through 6), all vehicle types, with the exception of auto transport, on average travel less than 30,000 miles per year. The average miles traveled for medium trucks is less 15,000 and they have a useful life of about nine and one half years. Heavy trucks, depending on type, travel from 37,600 miles to 86,500 miles per year and are kept in use for approximately 6 to 10 years. One of the more interesting findings was the significant difference in fuel economy among the vehicle types.

In the HVMP model, the truck classes are further segmented according to refueling location (i.e. central or multiple locations). As shown in Exhibit 3-14, all vehicle segments have central refueling occurring at least 43.5% of the time. As vehicles age, central refueling declines. We suspect that as centrally refueled vehicles age, they are transitioned from larger fleet operations to small independent owner operators.

Exhibit 3-14: Heavy Vehicle Characteristics

Vehicle Type	Average Annual Miles (1)	Average Lifetime	Fuel Economy	Percent Centrally Refueled (1)
Class 3-6	14,450	9.62	7.9 mpg	46.5%
Class 7&8 -Type 1	37,600	9.65	4.5 mpg	61.0%
Class 7&8 -Type 2	64,600	9.57	6.1 mpg	48.5%
Class 7&8 -Type 3	86,500	6.13	7.7 mpg	43.5%

(1) Vehicles 2 years old or less.

Overall market characteristics for vehicle stock, travel, and fuel use were also examined using the TIUS data. The data revealed that although medium trucks account for 57.6% of the heavy vehicle stock, they account for only 27.3% of vehicle miles traveled and 21.5% of fuel use. As expected, the data show that Class 7&8 vehicles account for a significant amount of travel and fuel use in the heavy vehicle market, 72.7% and 78.5% respectively. It is also important to note that Type 3 vehicles show the greatest utilization, accounting for 38.9% of all fuel use and 41.0% of all travel in the heavy vehicle market.

In addition to the market characterization, historical market penetration data was obtained from TIUS surveys for energy conserving technologies including radial tires, aerodynamic devices, and fan clutches. This data was utilized in the calibration of the model. (Ref. 6).

Exhibit 3-15: Market Characteristics

Vehicle Type	Percent of Total Vehicle Stock	Percent of Total VMT	Percent of Total Fuel Use
Class 3-6	57.6%	27.3%	21.5%
Class 7&8	42.4%	72.7%	78.5%
Type 1	12.1%	11.8%	13.6%
Type 2	16.1%	22.2%	23.9%
Type 3	14.1%	38.9%	41.0%

The HVMP model estimates market penetration based on cost effectiveness of the new technology. Cost effectiveness is measured as the incremental cost of the new technology less the discounted expected energy savings of that technology over a specified time period.

Exhibit 3-16 shows the payback distribution assumed in the HVMP model. This payback distribution was generated using data taken from a survey of 224 motor carriers conducted by the American Trucking Association. (Ref. 7)

Exhibit 3-16: Payback Periods

Number of Years	Percent of Motor Carriers
1	16.4%
2	61.7%
3	15.5%
4	6.4%

The new technology cost and the expected efficiency improvements are exogenous inputs. Energy savings are calculated using the following data and assumptions:

- Annual vehicle miles traveled;
- Fuel efficiency (mpg) without new technology (Ref. 6);
- Fuel efficiency (mpg) with new technology
- Projected fuel price – diesel, ethanol, and CNG (Ref. 8);

- Incremental Cost of new technology over time (economies of scale);
- Discount rate; and
- Payback period.

Eleven travel categories are represented in the model. These categories were determined using travel distributions developed with the TIUS data by Stacey Davis of ORNL (Ref. 9). Graphs of the actual data are shown for each market segment as well as the market distribution developed for the HVMP model.

As Exhibits 3-17 and 3-18 show, the majority of medium duty trucks travel less than 30,000 miles per year and very few travel more than 50,000 miles per year.

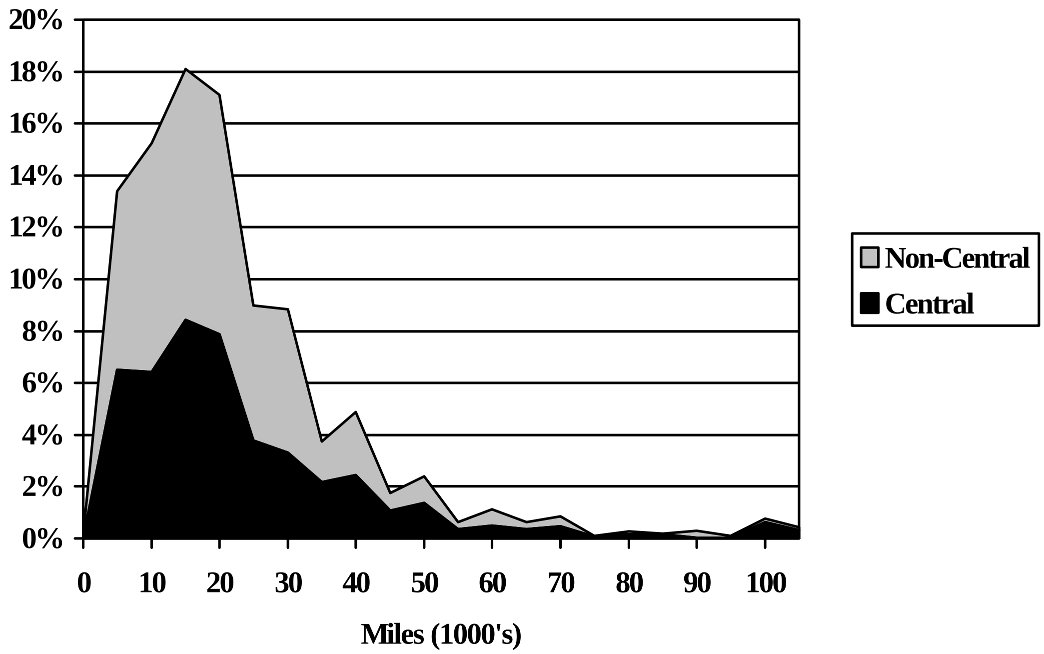
Exhibit 3-17: Medium Vehicle Travel Distribution in the HVMP Model

VMT (1000's)	Central Refueling	Non-Central Refueling
0 - 19.9	21.40%	25.48%
20 – 39.9	17.10%	21.57%
40 – 59.9	5.27%	4.40%
60 – 79.9	1.42%	1.30%
80 – 99.9	0.37%	0.49%
100+	0.95%	0.24%

Source: Reference 6.

Exhibit 3-18: Actual Medium Vehicle Travel Distribution

Source: Reference 6.



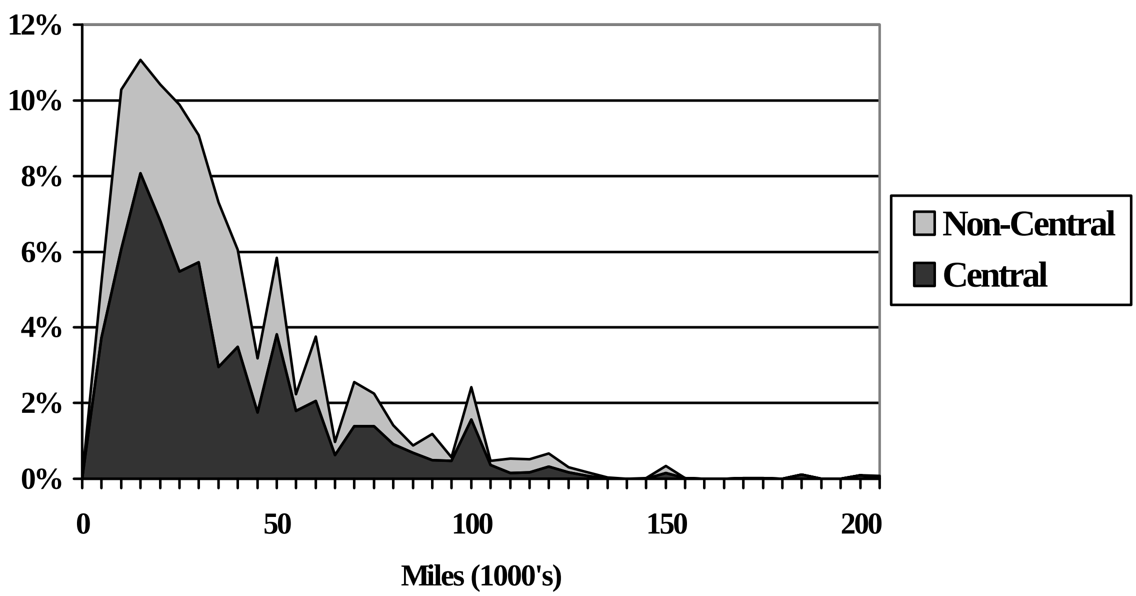
As shown in Exhibits 3-19 and 3-20, type 1 vehicles exhibit travel patterns similar to that of medium vehicles. The majority of travel is less than 50,000 miles per year. There are fewer non-centrally refueled vehicles in the Type 1 market segment, but both segments have very similar travel characteristics.

Exhibit 3-19: Type 1 Vehicle Travel Distribution in the HVMP Model

VMT (1000's)	Central Refueling	Non-Central Refueling
0 - 19.9	17.87%	8.66%
20 – 39.9	20.97%	15.73%
40 – 59.9	10.85%	6.46%
60 – 79.9	5.47%	4.08%
80 – 99.9	2.57%	1.48%
100 119.9	2.25%	1.69%
120 – 139.9	0.56%	0.61%
140 – 159.9	0.18%	0.20%
160 – 179.9	0.03%	0.00%
180 – 199.9	0.12%	0.00%
200+	0.10%	0.08%

Source: Reference 6.

Exhibit 3-20: New Type 1 Heavy Vehicle Travel Distribution



Source: Reference 6.

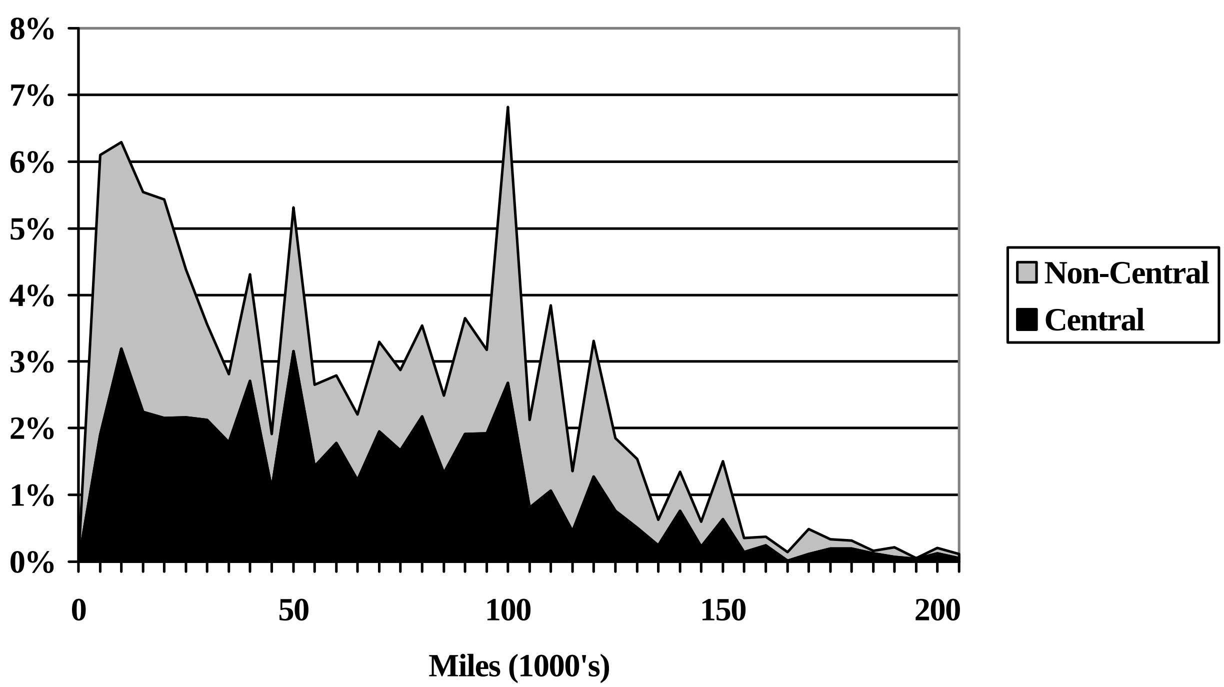
As shown in Exhibits 3-21 and 3-22, the Type 2 vehicle travel distribution shows travel peaks at both the upper and lower ranges. Further analysis may reveal that some vehicle types in this segment may fit better in the Type 1 or Type 3 segment. As expected, travel in this market segment increases significantly for both the central and non-centrally fueled vehicles.

Exhibit 3-21: Type 2 Vehicle Travel Distribution in the HVMP Model

VMT (1000's)	Central Refueling	Non-Central Refueling
0 - 19.9	7.36%	10.59%
20 – 39.9	8.22%	7.96%
40 – 59.9	8.39%	5.80%
60 – 79.9	6.62%	4.55%
80 – 99.9	7.33%	5.54%
100 119.9	5.02%	9.13%
120 – 139.9	2.78%	4.56%
140 – 159.9	1.75%	2.05%
160 – 179.9	0.55%	0.79%
180 – 199.9	0.42%	0.31%
200+	0.17%	0.13%

Source: Reference 6.

Exhibit 3-22: New Type 2 Heavy Vehicle Travel by Refueling Category



Source: Reference 6.

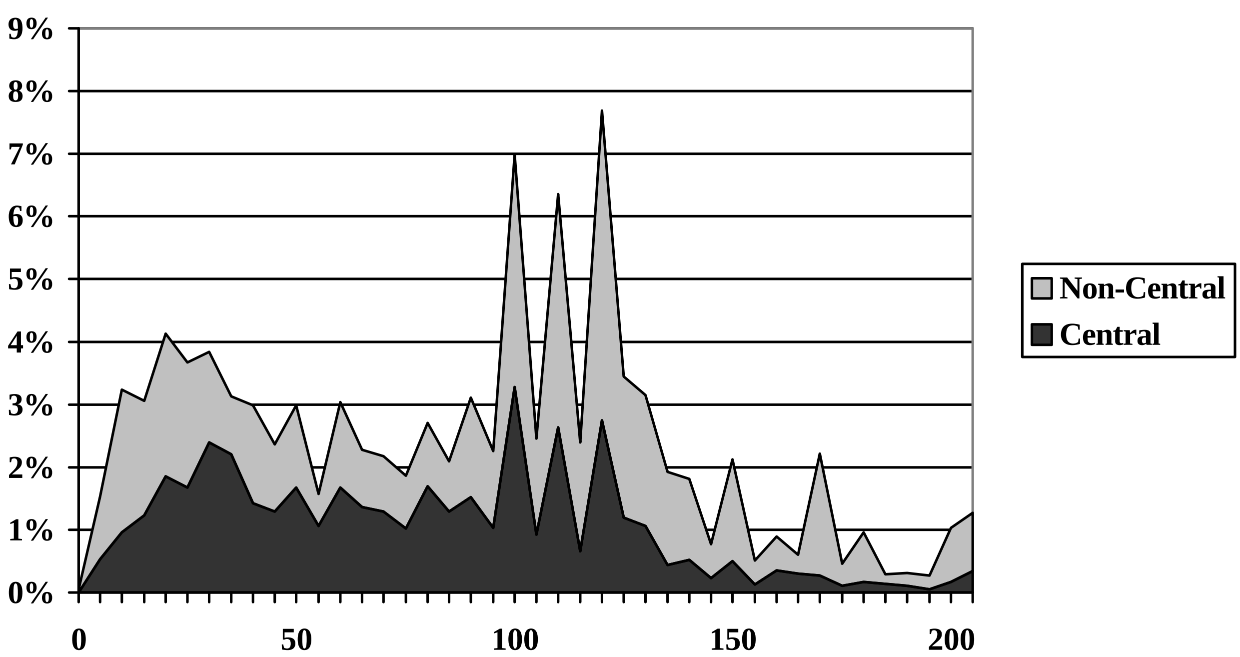
As shown in Exhibits 3-23 and 3-24, type 3 vehicles experience the greatest amount of annual travel. Centrally refueled vehicles travel less per year than non-centrally refueled vehicles. In the non-centrally refueled vehicle segment, the majority of travel occurs at 100,000 miles per year or more. In the central refueling segment, the majority of travel occurs below 100,000 miles per year.

Exhibit 3-23: Type 3 Vehicle Travel Distribution in the HVMP Model

VMT (1000's)	Central Refueling	Non-Central Refueling
0 - 19.9	2.72%	5.16%
20 – 39.9	8.12%	6.64%
40 – 59.9	5.45%	4.47%
60 – 79.9	5.35%	4.00%
80 – 99.9	5.55%	4.61%
100 119.9	7.50%	10.70%
120 – 139.9	5.44%	10.76%
140 – 159.9	1.37%	3.38%
160 – 179.9	1.03%	3.15%
180 – 199.9	0.47%	1.37%
200+	0.50%	1.79%

Source: Reference 6.

Exhibit 3-24: New Type 3 Heavy Vehicle Travel by Refueling Category



Source: Reference 6.

Technologies considered in the QM 2000 include natural gas engines, advanced diesel engines that are highly efficient and emit low levels of pollution, and hybrid drive trains in the medium market segment. The incremental vehicle costs of the advanced heavy vehicle technologies are indicated in Exhibit 3-25. The table implicitly indicates the assumption that as a new technology is introduced into the market place and sales shares increase, costs are reduced.

Exhibit 3-25: Incremental Costs for Heavy Vehicles ($1996)

Technology	2000	2005	2010	2020
Class 3-6 Natural Gas	N/A	6,000	4,000	4,000
Class 3-6 Hybrid	N/A	3,800	2,000	2,000
Class 7&8 Natural Gas	N/A	9,000	9,000	6,500
Class 7&8 Advanced Diesel	4,000	3,000	2,500	2,000

Exhibit 3-26 illustrates market penetration forecasts for heavy vehicles. For the assumptions utilized, the natural gas truck characteristics are not economically competitive except for in the year 2000 in Class 7 and 8 trucks. Advanced diesel technology has the best penetration in Type 3 trucks, which have the greatest utilization level. Penetration in Type 2 trucks is also significant. Advanced diesel penetration in Class 3 through trucks is limited for the hybrid vehicles.

Exhibit 3-26: Heavy Vehicle Market Penetration Results
(all values are percent of new vehicle sales)

Technology	2000	2005	2010	2020
Class 3-6 Hybrid	0.0%	0.5%	2.0%	2.6%
Class 3-6 Natural Gas	0.0%	0.0%	0.0%	0.0%
Class 7&8 Type 1 Adv. Diesel	2.6%	4.0%	5.6%	12.0%
Class 7&8 Type 1 Natural Gas	0.2%	0.0%	0.0%	0.0%
Class 7&8 Type 2 Adv. Diesel	4.6%	7.0%	10.4%	23.7%
Class 7&8 Type 2 Natural Gas	0.3%	0.0%	0.0%	0.0%
Class 7&8 Type 3 Adv. Diesel	4.3%	6.6%	10.1%	23.8%
Class 7&8 Type 3 Natural Gas	0.1%	0.0%	0.0%	0.0%

3.3 Sensitivity Studies

Analyses were conducted to examine market penetration sensitivity to fuel price, vehicle cost, and fuel efficiency for the light and heavy vehicle markets. For the light vehicle sector, the VCSS model was used to conduct market sensitivities. In the heavy vehicle sector, the HVMP model was used. The sensitivity analyses are compared to a reference case that reflects the assumptions made for the Quality Metrics 2000.

The fuel price scenarios include the following assumptions:

1. Annual Energy Outlook 1998 Reference Case,
2. Annual Energy Outlook 1998 High Economic Case, and
3. Double the fuel price in the Annual Energy Outlook 1998 Reference Case.

For vehicle cost, the incremental vehicle cost was reduced by fifty percent (50%). For vehicle fuel efficiency, the incremental efficiency was increased by fifty percent (50%). All other vehicle and fuel attributes reflect the assumptions used in the Quality Metrics 2000 reference case.

Exhibit 3-27 shows the market penetration results for the light vehicle sector. Increasing the fuel price to the AEO'98 High Economic Case had virtually no effect on market penetration. Doubling fuel prices resulted in a shift away from conventional technologies to advanced electric drive vehicles. Dedicated electric vehicles and fuel cell vehicles had the greatest increase in market penetration. Reducing vehicle cost and improving efficiency resulted in slight marginal improvements in market penetration.

Exhibit 3-28 shows the sensitivity impacts in the heavy vehicle sector. Because the HVMP model strictly functions as an economic model, there was significantly more sensitivity to the inputs. Market penetration increased considerably in the AEO'98 High Economic Case and dramatically in the double fuel price case. For the decreased incremental vehicle cost and the increased fuel efficiency cases, the market penetration more than doubled for each case.

Exhibit 3-27: Light Vehicle Market Sensitivity Runs to Fuel Price, Vehicle Price, and Vehicle Efficiency

							Incremental Vehicle Cost Reduced By 50%					
	AEO'98 Ref.		AEO'98 High Econ.		2X Fuel Price		AEO'98 Ref.		AEO'98 High Econ.		2X Fuel Price	
	2010	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Fuel Prices												
Gasoline	1.27	1.28	1.33	1.36	2.54	2.56	1.27	1.28	1.33	1.36	2.54	2.56
Diesel	1.19	1.18	1.24	1.25	2.38	2.35	1.19	1.18	1.24	1.25	2.38	2.35
CNG	0.84	0.94	0.88	0.97	1.68	1.87	0.84	0.94	0.88	0.97	1.68	1.87
Electricity	1.67	1.54	1.73	1.62	3.34	3.08	1.67	1.54	1.73	1.62	3.34	3.08
Ethanol	1.28	1.15	1.28	1.15	2.56	2.30	1.28	1.15	1.28	1.15	2.56	2.30
Percent Change in Fuel Price												
Gasoline			4.7%	6.3%	100.0%	100.0%	0.0%	0.0%	4.7%	6.3%	100.0%	100.0%
Diesel			4.2%	5.9%	100.0%	99.2%	0.0%	0.0%	4.2%	5.9%	100.0%	99.2%
CNG			4.8%	3.2%	100.0%	98.9%	0.0%	0.0%	4.8%	3.2%	100.0%	98.9%
Electricity			3.6%	5.2%	100.0%	100.0%	0.0%	0.0%	3.6%	5.2%	100.0%	100.0%
Ethanol			0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
Market Penetration												
Conventional	37.2%	34.1%	37.1%	33.9%	35.0%	31.7%	36.5%	33.2%	36.4%	33.0%	34.3%	30.8%
Flex Alcohol	4.6%	4.1%	4.6%	4.1%	4.3%	3.9%	4.5%	4.0%	4.5%	4.1%	4.2%	3.8%
SDI	20.2%	18.1%	20.2%	18.0%	20.0%	17.7%	20.2%	17.9%	20.2%	17.9%	19.9%	17.5%
Advanced Diesel	19.5%	20.3%	19.6%	20.3%	20.3%	20.8%	19.9%	20.6%	19.9%	20.6%	20.6%	21.1%
CNG	2.0%	1.6%	2.0%	1.6%	2.1%	1.6%	2.0%	1.6%	2.0%	1.6%	2.2%	1.6%
Electric	2.5%	1.8%	2.5%	1.8%	3.1%	2.2%	2.7%	2.0%	2.7%	2.0%	3.4%	2.4%
Hybrid	11.7%	14.0%	11.7%	14.0%	12.7%	15.1%	11.8%	14.3%	11.9%	14.4%	12.8%	15.5%
Fuel Cell	2.2%	6.1%	2.3%	6.1%	2.5%	7.0%	2.3%	6.4%	2.3%	6.4%	2.6%	7.3%
Percent Change in Market Penetration												
Conventional			-0.3%	-0.6%	-5.9%	-7.0%	-1.9%	-2.6%	-2.2%	-3.2%	-7.8%	-9.7%
Flex Alcohol			0.0%	0.0%	-6.5%	-4.9%	-2.2%	-2.4%	-2.2%	0.0%	-8.7%	-7.3%
SDI			0.0%	-0.6%	-1.0%	-2.2%	0.0%	-1.1%	0.0%	-1.1%	-1.5%	-3.3%
Advanced Diesel			0.5%	0.0%	4.1%	2.5%	2.1%	1.5%	2.1%	1.5%	5.6%	3.9%
CNG			0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	0.0%
Electric			0.0%	0.0%	24.0%	22.2%	8.0%	11.1%	8.0%	11.1%	36.0%	33.3%
Hybrid			0.0%	0.0%	8.5%	7.9%	0.9%	2.1%	1.7%	2.9%	9.4%	10.7%
Fuel Cell			4.5%	0.0%	13.6%	14.8%	4.5%	4.9%	4.5%	4.9%	18.2%	19.7%

Exhibit 3-27: Light Vehicle Market Sensitivity Runs to Fuel Price, Vehicle Price, and Vehicle Efficiency (Continued)

	Increase Incremantal Fuel Efficiency by 50%						Inc. Veh. Cost Red. By 50% & High Efficiency					
	AEO'98 Ref.		AEO'98 High Econ.		2X Fuel Price		AEO'98 Ref.		AEO'98 High Econ.		2X Fuel Price	
	2010	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Fuel Prices												
Gasoline	1.27	1.28	1.33	1.36	2.54	2.56	1.27	1.28	1.33	1.36	2.54	2.56
Diesel	1.19	1.18	1.24	1.25	2.38	2.35	1.19	1.18	1.24	1.25	2.38	2.35
CNG	0.84	0.94	0.88	0.97	1.68	1.87	0.84	0.94	0.88	0.97	1.68	1.87
Electricity	1.67	1.54	1.73	1.62	3.34	3.08	1.67	1.54	1.73	1.62	3.34	3.08
Ethanol	1.28	1.15	1.28	1.15	2.56	2.30	1.28	1.15	1.28	1.15	2.56	2.30
Percent Change in Fuel Price												
Gasoline	0.0%	0.0%	4.7%	6.3%	100.0%	100.0%	0.0%	0.0%	4.7%	6.3%	100.0%	100.0%
Diesel	0.0%	0.0%	4.2%	5.9%	100.0%	99.2%	0.0%	0.0%	4.2%	5.9%	100.0%	99.2%
CNG	0.0%	0.0%	4.8%	3.2%	100.0%	98.9%	0.0%	0.0%	4.8%	3.2%	100.0%	98.9%
Electricity	0.0%	0.0%	3.6%	5.2%	100.0%	100.0%	0.0%	0.0%	3.6%	5.2%	100.0%	100.0%
Ethanol	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
Market Penetration												
Conventional	36.6%	33.4%	37.2%	33.2%	33.8%	30.3%	35.9%	32.5%	35.8%	32.3%	33.0%	29.4%
Flex Alcohol	4.5%	4.0%	4.4%	4.1%	4.1%	3.8%	4.4%	4.0%	4.4%	4.0%	4.1%	3.7%
SDI	20.4%	18.1%	19.5%	18.1%	20.3%	17.8%	20.3%	18.0%	20.3%	18.0%	20.2%	17.6%
Advanced Diesel	19.7%	20.4%	19.5%	20.4%	20.6%	21.0%	20.1%	20.7%	20.1%	20.7%	21.0%	21.3%
CNG	2.0%	1.6%	1.9%	1.6%	2.1%	1.5%	2.0%	1.6%	2.0%	1.6%	2.1%	1.6%
Electric	2.5%	1.8%	2.3%	1.8%	3.1%	2.2%	2.7%	2.0%	2.8%	2.0%	3.4%	2.3%
Hybrid	12.1%	14.5%	12.2%	14.6%	13.5%	16.1%	12.2%	14.8%	12.3%	14.9%	13.6%	16.5%
Fuel Cell	2.2%	6.2%	3.1%	6.3%	2.5%	7.3%	2.3%	6.5%	2.3%	6.6%	2.6%	7.6%
Percent Change in Market Penetration												
Conventional	-1.6%	-2.1%	0.0%	-2.6%	-9.1%	-11.1%	-3.5%	-4.7%	-3.8%	-5.3%	-11.3%	-13.8%
Flex Alcohol	-2.2%	-2.4%	-4.3%	0.0%	-10.9%	-7.3%	-4.3%	-2.4%	-4.3%	-2.4%	-10.9%	-9.8%
SDI	1.0%	0.0%	-3.5%	0.0%	0.5%	-1.7%	0.5%	-0.6%	0.5%	-0.6%	0.0%	-2.8%
Advanced Diesel	1.0%	0.5%	0.0%	0.5%	5.6%	3.4%	3.1%	2.0%	3.1%	2.0%	7.7%	4.9%
CNG	0.0%	0.0%	-5.0%	0.0%	5.0%	-6.3%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%
Electric	0.0%	0.0%	-8.0%	0.0%	24.0%	22.2%	8.0%	11.1%	12.0%	11.1%	36.0%	27.8%
Hybrid	3.4%	3.6%	4.3%	4.3%	15.4%	15.0%	4.3%	5.7%	5.1%	6.4%	16.2%	17.9%
Fuel Cell	0.0%	1.6%	40.9%	3.3%	13.6%	19.7%	4.5%	6.6%	4.5%	8.2%	18.2%	24.6%

Exhibit 3-28: Heavy Vehicle Market Sensitivity Runs to Fuel Price, Vehicle Price, and Vehicle Efficiency

							Incremental Vehicle Cost Reduced By 50%							**Increase Incremantal Fuel Efficiency by 50%**						
	AEO'98 Ref.		AEO'98 High Econ		2X Fuel Price		AEO'98 Ref.		AEO'98 High Econ		2X Fuel Price			AEO'98 Ref.		AEO'98 High Econ		2X Fuel Price	
	2010	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**		**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Fuel Prices																			
Gasoline	1.27	1.28	1.33	1.36	2.54	2.56	1.27	1.28	1.33	1.36	2.54	2.56	Gasoline	1.27	1.28	1.33	1.36	2.54	2.56
Diesel	1.19	1.18	1.24	1.25	2.38	2.35	1.19	1.18	1.24	1.25	2.38	2.35	Diesel	1.19	1.18	1.24	1.25	2.38	2.35
CNG	0.84	0.94	0.88	0.97	1.68	1.87	0.84	0.94	0.88	0.97	1.68	1.87	CNG	0.84	0.94	0.88	0.97	1.68	1.87
Electricity	1.67	1.54	1.73	1.62	3.34	3.08	1.67	1.54	1.73	1.62	3.34	3.08	Electricity	1.67	1.54	1.73	1.62	3.34	3.08
Ethanol	1.28	1.15	1.28	1.15	2.56	2.30	1.28	1.15	1.28	1.15	2.56	2.30	Ethanol	1.28	1.15	1.28	1.15	2.56	2.30
Percent Change in Fuel Price																			
Gasoline			4.7%	6.3%	100.0%	100.0%	0.0%	0.0%	4.7%	6.3%	100.0%	100.0%	Gasoline	0.0%	0.0%	4.7%	6.3%	100.0%	100.0%
Diesel			4.2%	5.9%	100.0%	99.2%	0.0%	0.0%	4.2%	5.9%	100.0%	99.2%	Diesel	0.0%	0.0%	4.2%	5.9%	100.0%	99.2%
CNG			4.8%	3.2%	100.0%	98.9%	0.0%	0.0%	4.8%	3.2%	100.0%	98.9%	CNG	0.0%	0.0%	4.8%	3.2%	100.0%	98.9%
Electricity			3.6%	5.2%	100.0%	100.0%	0.0%	0.0%	3.6%	5.2%	100.0%	100.0%	Electricity	0.0%	0.0%	3.6%	5.2%	100.0%	100.0%
Ethanol			0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%	Ethanol	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
Market Penetration																			
Class 3-6																			
Hybrid	3.4%	2.9%	3.8%	3.4%	16.4%	13.7%	16.4%	14.0%	18.5%	16.3%	49.7%	47.6%	Hybrid	6.5%	5.6%	7.3%	6.4%	25.7%	23.0%
CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class 7-8																			
Adv. Diesel	9.2%	23.2%	10.8%	26.4%	44.1%	57.6%	44.1%	57.7%	46.8%	59.3%	68.1%	77.3%	Adv. Diese	22.1%	41.9%	24.5%	46.0%	57.1%	67.3%
CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
T1 - Adv. Diesel	5.6%	12.8%	6.4%	14.4%	24.1%	38.1%	24.1%	38.4%	25.1%	40.6%	51.9%	69.8%	T1 - Adv. D	12.2%	22.8%	13.5%	24.7%	37.0%	50.3%
T1 - CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	T1 - CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
T2 - Adv Diesel	10.2%	25.5%	11.8%	28.4%	45.3%	57.1%	45.3%	57.2%	47.0%	58.3%	68.3%	73.8%	T2 - Adv D	24.3%	43.4%	26.9%	46.6%	56.8%	67.9%
T2 - CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	T2 - CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
T3 - Adv Diesel	9.9%	25.5%	11.7%	29.4%	50.2%	64.2%	50.2%	64.3%	53.8%	65.9%	73.3%	81.5%	T3 - Adv D	24.2%	47.4%	26.9%	52.6%	63.8%	72.6%
T3 - CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	T3 - CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Percent Change in Market Penetration																			
Class 3-6																			
Hybrid			11.8%	17.2%	382.4%	372.4%	382.4%	382.8%	444.1%	462.1%	1361.8%	1541.4%	Hybrid	91.2%	93.1%	114.7%	120.7%	655.9%	693.1%
CNG			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class 7-8																			
Adv. Diesel			17.4%	13.8%	379.3%	148.3%	379.3%	148.7%	408.7%	155.6%	640.2%	233.2%	Adv. Diese	140.2%	80.6%	166.3%	98.3%	520.7%	190.1%
CNG			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
T1 - Adv. Diesel			14.3%	12.5%	330.4%	197.7%	330.4%	200.0%	348.2%	217.2%	826.8%	445.3%	T1 - Adv. D	117.9%	78.1%	141.1%	93.0%	560.7%	293.0%
T1 - CNG			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	T1 - CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
T2 - Adv Diesel			15.7%	11.4%	344.1%	123.9%	344.1%	124.3%	360.8%	128.6%	569.6%	189.4%	T2 - Adv D	138.2%	70.2%	163.7%	82.7%	456.9%	166.3%
T2 - CNG			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	T2 - CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
T3 - Adv Diesel			18.2%	15.3%	407.1%	151.8%	407.1%	152.2%	443.4%	158.4%	640.4%	219.6%	T3 - Adv D	144.4%	85.9%	171.7%	106.3%	544.4%	184.7%
T3 - CNG			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	T3 - CNG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

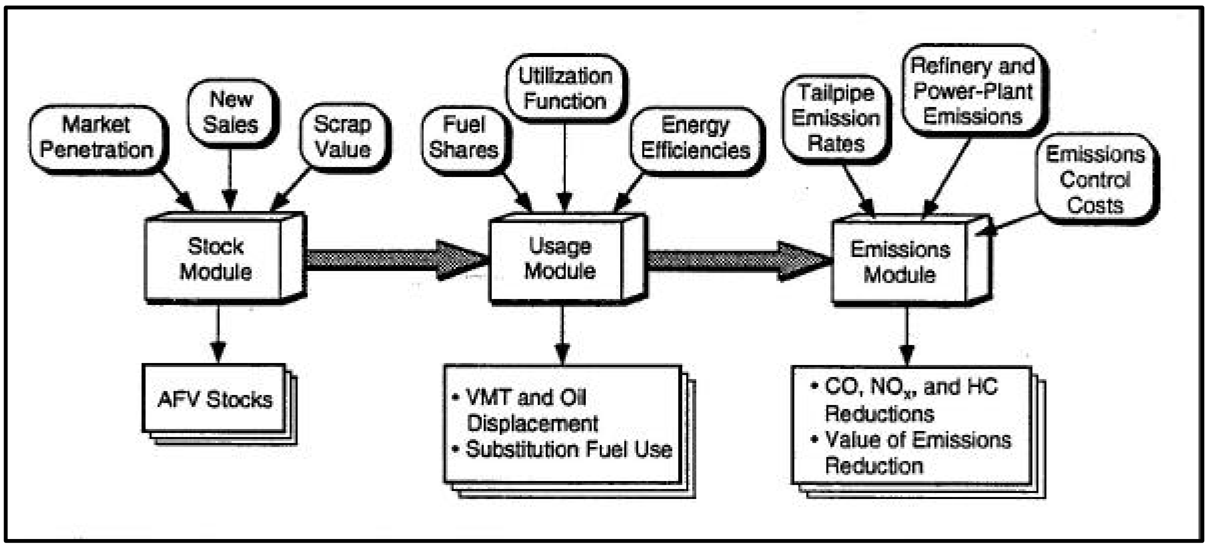
4.0 Petroleum and Other Energy Benefits Analysis

4.1 Analytical Tools

Integrated Market Penetration and Anticipated Cost of Transportation Technologies (IMPACTT) Model

The IMPACTT model is a spreadsheet model that calculates the effect of advanced-technology vehicles and market penetration on baseline fuel use and emissions (Ref. 9). IMPACTT conceptually consists of sixteen (16) modules, the largest of which is the vehicle stock and usage model. In the current version of IMPACTT, up to eight (8) fuel or engine technologies applicable to light vehicles can be modeled by using a three-phase approach. The impact model structure is indicated in Exhibit 4-1.

Exhibit 4-1: IMPACTT Model Structure



Source: Reference 10.

- First, the vehicle stock and miles traveled by the advanced-technology vehicle are determined. The vehicle stock and usage module is based on a capital vintaging model developed by Greene and Rathi. It calculates vehicle stock, annual miles traveled, and fuel displaced. (Ref. 11)
- Second, assumptions about efficiency and fuel shares are used to estimate substitution-fuel use and oil displacement. Technology specific parameters such as gasoline equivalent fuel economy, and conversion efficiency values are used, as appropriate, to compute alternative fuel consumption.
- Third, changes in emissions of carbon monoxide, non-methane hydrocarbons, nitrogen oxides, and carbon dioxide are computed. Emissions rates (in grams per mile) are modeled as a function of vehicle age.

Outputs include:

- Estimates of the quantity and value of oil displaced and emissions reduced by advanced-technology vehicles;
- The quantity of alternative fuels they consume; and
- Total incremental costs borne by purchasers of advanced-technology vehicles.

These estimates are based on exogenous projections of light vehicle sales, advanced-technology market penetration, and the characteristics of new conventional and advanced-technology vehicles. Vehicle characteristics include:

- Fuel efficiency;
- Tailpipe emissions of nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane hydrocarbons (NMHCs) as estimated using the EPA Mobile model 5a; and
- Incremental capital cost of the advanced technology.

Annual petroleum displacement and emission reductions are calculated by projecting the miles traveled by each model year's conventional vehicles, their petroleum use, and their emissions; and then subtracting from this the projections for comparable projections for advanced technology vehicles.

Alternative Fuels

Ethanol fuel use estimates are based on supply projections provided by the Office of Fuels Development (OFD- Ref. 12). The cellulosic ethanol goals for FY2000 and beyond are indicated below in Exhibit 4-2. All values are in million gallons per year. Initial production is expected to occur at two plants. The Masada Resources' plant is assumed to start up in 2001 and a second plant, BCI/Jennings in 2002. Subsequent plants expected to start ethanol production are:

- Arkenol in 2003;
- Gridley/BCI's (2 plants) in 2004;
- Quincy Library Group's softwoods plant and corn fiber add-ons to corn ethanol plants in 2005;
- Masada's and BCI's new plants in 2006;
- Corn fiber, stover, and softwoods plants in 2007.

The growth of cellulosic ethanol is reduced by 2015 because the blend market is saturated in view of Reed Vapor Pressure constraints and other factors analyzed by the OFD refinery model.

Exhibit 4-2: Ethanol Fuel Supply Projection of the Office of Fuels Development

Year	2000	2001	2002	2003	2004	2005	2010	2015	2020
Incremental million gallons per year		6	20	24	50	500	100 0	500	500
Total million gallons per year	**0**	**6**	**26**	**50**	**100**	**600**	**4000**	**8500**	**11000**

Alternative fuel demand is estimated as the amount of fuel required by dedicated fuel vehicles plus fuel demanded by multifuel and flex-fuel vehicles. Alternative fuel choice for multifuel and flex-fuel vehicles is estimated using consumer derived utility values associated with the attributes of the fuel. The fuel attributes include:

- Fuel price in dollars per gallon of gasoline equivalent (125,000 Btu);
- Fuel availability (percent of stations offering the fuel); and
- Vehicle range associated with the use of that fuel.

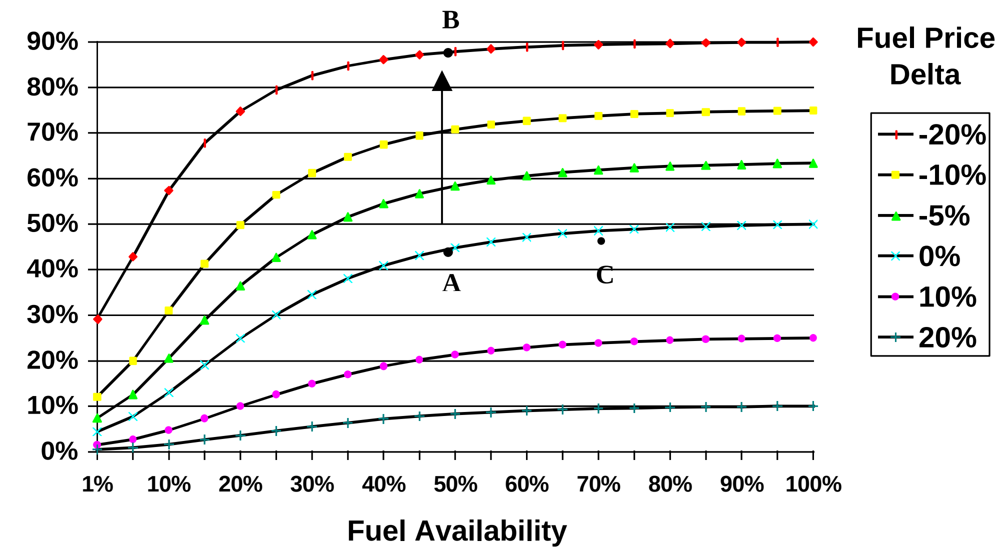
Exhibit 4-3 shows the amount of fuel demanded by flex-fuel vehicles and the use of fuel blends and extenders. The exhibit summarizes a detailed year-by-year estimate of biofuel demand for each technology which is presented in Appendix A. Fuel demand is constrained to match supply as indicated in Exhibit 4-2. Ethanol is used in *fuel blends* in order to meet EPA requirements such as Reformulated Gasoline (RFG) and winter oxygenation. Ethanol is used as an *extender* in gasoline blends to reduce petroleum consumption even in regions of the U.S. that need no RFG or oxygenated fuel. The factors affecting the demand for ethanol as a fuel extender (e.g. patriotism, concern for local corn growers, etc.) are likely to be different from those with an effect on the demand for the other kinds of blends.

Exhibit 4-3: Biomass Fuel Use

ITEM	2000	2010	2020
Direct Biomass Ethanol Use (million gallons per year)	1.3	282.2	924.6
Blends and Extenders (million gallons per year)	0	4,000	11,000
Program Supply Goal (million gallons)	1.3	4,282	11,925
E-85 Share of Fuel Used by FFVs (Table A-12)	0.1%	4.1%	14.2%

Alternative fuel consumer utility values are compared to values for conventional fuels, when fuel choice estimations are made. Exhibit 4-4 shows the amount of time it is estimated that consumers will choose an alternative fuel over the conventional when operating a flex-fuel or multifuel vehicle. This graph illustrates the relationship between fuel availability and fuel price. For example, at fifty percent (50%) availability and a zero cost increment, the alternative fuel should be chosen forty-five percent (45%) of the time (Point A). If the price increment is decreased twenty percent (20%), it is estimated the alternative fuel will be chosen nearly 90% of the time (Point B). Whereas, if fuel availability is increased to seventy percent (70%) only marginal increases in alternative fuel selection occur (to 49% at Point C). The calculations for this graph assume no range penalty for using the alternative fuel.

Exhibit 4-4: Alternative Fuel Market Share as a Function of Fuel Availability and Fuel Price (Ref. 3)



Points A, B, and C are explained in text

4.2 Estimates of the Value of Reducing Imported Oil

Many researchers have developed estimates of the magnitude and cause of cost premiums associated with importing oil. The oil import premium exists because the market price of oil does not cover the societal cost incurred by importing. In order to calculate the value of an alternative to imported oil, one must add the market price of oil to the import premium. The "categories" of the oil import premiums, the rationale for including an oil import premium, and the range of estimates for the value of the oil import premium are explained in this section.

<u>Definitions of the Components of an Imported Oil Premium</u>

Externalities associated with imported oil can be defined as follows: demand costs ("market power" or monopsony effects, plus indirect effects such as inflation and balance of payments), disruption costs (economic losses due to price spikes), direct military costs (expenditures to maintain a military presence in oil producing regions), and environmental costs (costs due to oil spills and other environmental problems associated with importing oil). The demand and disruption costs are the most commonly used measure of an oil import premium (Ref. 13).

Demand costs can be broken into a direct and indirect component. The direct component is known as the "market power" or monopsony effects. Monopsony costs occur when the increase in the demand for imported oil causes world oil prices to rise, thus increasing the costs of all imports, not just the incremental demand. Not only is the added cost born by the demander responsible for the increase, but by all importers equally. The market power premium can be illustrated by a simple example. Suppose the U.S. were importing 5.5 million barrels of oil a day at a price of $30 per barrel. Then the daily import bill would be $165 million. If increasing imports to 6.0 million barrels per day causes prices to rise to $31 per barrel, the daily import bill becomes $186 million. In this situation, the importing country bears an additional cost of $21 million per day in order to import an additional 0.5 million barrels per day. The cost to the economy is $42 per additional barrel of oil imported. Since the individual oil importers initially pay only $30 per barrel, the remainder -- $12 per barrel -- is a cost not borne by those who decide to import more oil. In this case, the market power premium is $12 per barrel.

Indirect costs are the macroeconomic costs of importing oil such as inflation impacts, lowering the level of savings, and terms of trade impacts. Imported oil bills increase the current account deficit in the U.S. balance of trade, leading to an excess supply of U.S. dollars in the foreign exchange market and thus lowering the buying power of U.S. consumers. Higher imported oil costs can lead to "structural" inflation that leads to adverse macroeconomic conditions.

Disruption or "security" costs can also be broken into direct and indirect components. The direct component is similar to the above direct component because it is the monopsony affect that occurs when prices increase due to a disruption. The indirect, or macroeconomic, component of disruption costs are associated with the depressed aggregate demand caused by the disruption and the accompanying higher inflation and unemployment.

The demand and disruption costs are traditional components of the calculation of an oil import premium. Somewhat untraditional and harder to quantify, additional components of the oil import premium are direct military expenditures and environmental costs. The military expenditures are some fraction of the costs to the U.S. to maintain a military presence in the Middle East to ensure continued access to oil. The environmental costs are less straightforward -- they primarily include the costs of oil spills and emissions from oil combustion. At this time, we have no estimates of the environmental costs. There are a variety of estimates of military costs based on the amount of military resources dedicated to the Persian Gulf region. Oak Ridge National Laboratory recently conducted a literature review and assessment of military costs to assure the supply of oil imports to the U.S. **After reviewing a variety of sources, it was estimated that the "social cost" of oil supply to the U.S. is $5/barrel (Ref. 14)**. This number was computed by dividing $32 billion by the amount of exported oil, 6.4 billion barrels.

Range of Estimates of Imported Oil Premium

Exhibit 4-3 identifies a range of estimates of an oil import premium (the market price of oil plus the oil import premium equals the value of reducing oil imports). They range from $1 to $225 depending on what is included in the estimate, the price of oil, and other assumptions. These values do not indicate whether or not the price of imported oil has an impact on its premium. Greene's estimates are slightly different than the other estimates because he calculates total social costs of imported oil (the oil premium plus the market oil import price) yearly based on the actual disruption costs. (The other analysts incorporate probabilities of disruptions in their estimates.) While Greene reports social costs, for comparison consistency, the value in the table is the equivalent oil import premium.

Impacts of Imported Oil

An examination of the economic literature suggests that there are economic costs and economic security costs associated with the use of imported oil. These costs will not be captured in the gross national product (GNP) estimates from the economic models that are used in our analysis. Therefore, these costs need to be subtracted from any GNP estimate.

Several types of costs are not captured in the standard economic valuations. These are:

- Demand costs that are caused by the oil price increases that will occur when U.S. demand increases, because the U.S. is in a monopsony position. This will have an effect on GDP.
- Disruption costs which reflect the expected economic costs of sudden shifts in oil price or availability due to possible political unrest in the Mid-East.
- Other costs which include the military costs of protecting Mid-East oil supplies and environmental costs associated with foreign oil production and transport.

The suggested cost associated with the use of imported oil, based on a subjective evaluation of the alternative estimates (Exhibit 4-5), and placing greater weight on estimates since 1990, is a nominal $5/barrel ($1996). This cost is in addition to the social cost of $5.00/barrel discussed previously.

Exhibit 4-5: Value of Reducing Imported Oil ($1996 per bbl)

Source		Value, 1990$ Demand Costs	Value, 1990$ Disruption Costs	Value, 1990$ Direct Military Costs	Value, 1990$ Total Costs	Value, 1996$ Demand Costs	Value, 1996$ Disruption Costs	Value, 1996$ Direct Military Costs	Value, 1996$ Total Costs	Notes
Stobaugh and Yergin (1979)	Low	$27			$27	$32			$32	
	High	$102			$102	$121			$121	
Stobaugh and Yergin (1980)	Low	$52			$52	$62			$62	
	High	$189			$189	$225			$225	
Lemon (1979)		$53	$6		$59	$63	$7		$70	
Lemon (1980)		$87	$21		$108	$104	$25		$129	
Nordhaus (1980)	Low	$0	$15		$20	$0	$18		$24	
	High	$38	$27		$70	$45	$32		$83	
Blankenship et al (1980)	Low				$6				$7	
	High				$15				$18	
Plummer (1981)	Low	$10	$5		$15	$12	$6		$18	
	High	$10	$32		$42	$12	$38		$50	
Hogan (1981)	Low	$0	$0		$3				$4	
	High	$39	$14		$56	$46	$17		$67	
EMF 6 (1981)	Low	$10	$0		$10	$12			$12	Based on 9 different models
	High	$21	$7		$28	$25	$8		$33	
NES (1990)	Low				$1				$1	
	High				$5				$6	
Broadman and Hogan (1988)	Low				$2				$2	
	High				$16				$19	
Greene and Leiby (ORNL, 1993)					$44			$2	$52	Greene estimates total GNP loss from imported oil from 1974 to 1990; the amount of imported oil during that period was used to get a $/bbl number.

4.3 Petroleum Reduction Estimates

Exhibit 4-6 shows the energy and oil that will be displaced as a result of the OTT programs discussed in this report. It can be seen that the total oil displacement that will occur in the year 2020 is almost 2 million barrels per day.

Exhibit 4-6: Energy Displaced

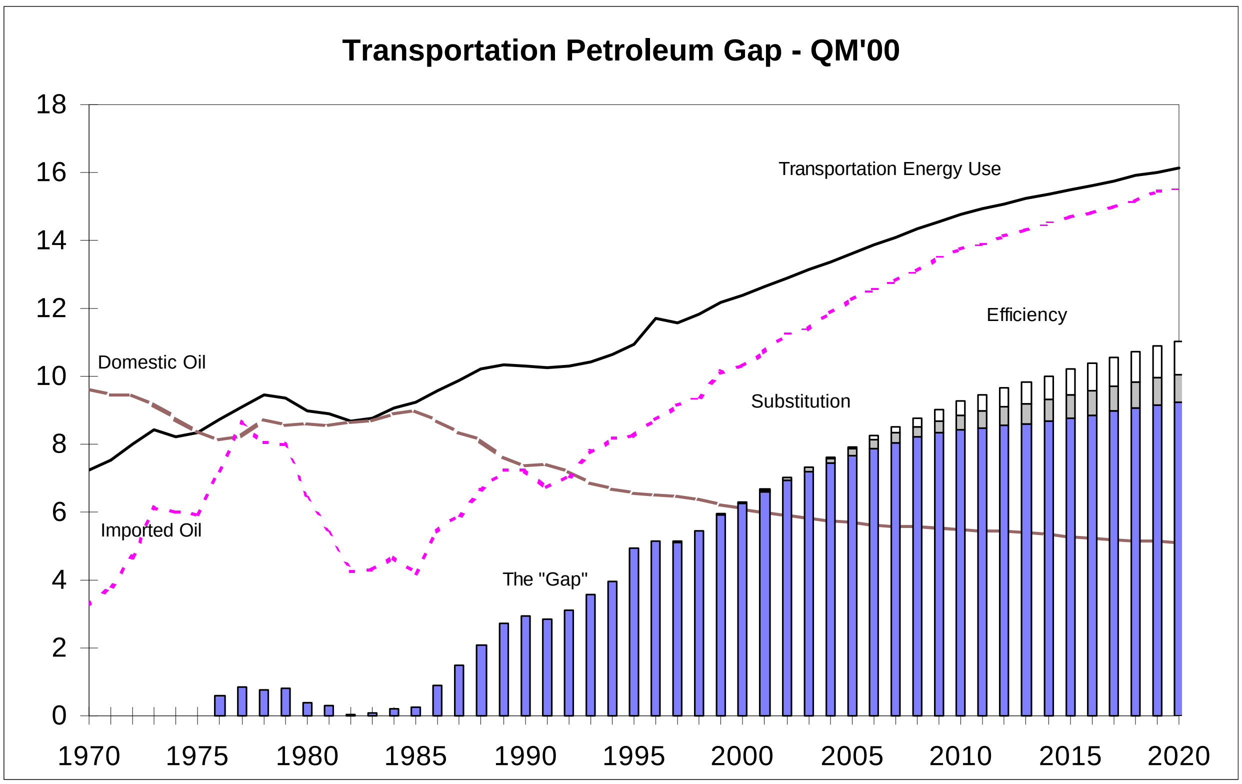
Technology	Primary Energy Displaced MBPD			Primary Oil Displaced MBPD		
	Year 2000	Year 2010	Year 2020	Year 2000	Year 2010	Year 2020
Technology Deployment	0.000	0.000	0.000	0.031	0.196	0.208
Biofuels	0.000	0.170	0.473	0.000	0.170	0.473
Flex-Fuel	0.000	0.010	0.033	0.000	0.010	0.033
Dedicated	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000
Blends & Extenders	0.000	0.160	0.440	0.000	0.160	0.440
Total Advanced Auto Tech	0.000	0.302	0.750	0.001	0.371	0.867
Electric Vehicle R&D	0.000	0.005	0.009	0.001	0.074	0.126
Fuel Cell Vehicle R&D	0.000	0.013	0.116	0.000	0.013	0.116
Hybrid Vehicle R&D	0.000	0.128	0.336	0.000	0.128	0.336
SDI	0.000	0.052	0.108	0.000	0.052	0.108
Light Duty Engine R&D	0.000	0.104	0.181	0.000	0.104	0.181
Heavy Vehicle R&D	0.003	0.096	0.187	0.004	0.097	0.187
Classes 1&2	0.000	0.058	0.099	0.000	0.058	0.099
Classes 3-8	0.003	0.038	0.088	0.004	0.039	0.088
Advanced Materials	0.000	0.006	0.023	0.000	0.012	0.035
Propulsion System	0.000	0.000	0.000	0.000	0.000	0.000
Light Vehicle	0.000	0.006	0.023	0.000	0.012	0.035
Electric Vehicle	0.000	0.001	0.001	0.000	0.007	0.012
Hybrid Vehicle	0.000	0.004	0.010	0.000	0.004	0.010
Fuel Cell Vehicle	0.000	0.001	0.013	0.000	0.001	0.013
Heavy Vehicle	0.000	0.000	0.000	0.000	0.000	0.000
Total	0.003	0.574	1.433	0.036	0.846	1.770
Baseline (AEO 98)	12.890	15.630	17.220	12.390	14.760	16.130
Percent Reduction	0.0%	3.7%	8.3%	0.3%	5.7%	11.0%

The energy use effects of current zero emission vehicle (ZEV) mandates and EPACT requirements are indicated in Exhibit 4-7. Exhibit 4-8 shows that the OTT programs will have the effect of decreasing the rise in oil use by transportation.

Exhibit 4-7: ZEV and EPACT Oil Reductions

Program	2000	2005	2010	2015	2020
ZEV Mandates, thousand barrels/day	1.15	20.62	41.39	55.35	66.97
EPACT, thousand barrels/day	0.40	0.97	0.74	0.72	0.72
Total	1.55	21.59	42.13	56.07	67.69

Exhibit 4-8: Transportation Petroleum Use Projection



5.0 Economic and Environmental Benefits Analysis

In this section, economic and environmental benefits analyses are presented. The scope of the OTT Impacts Assessments contains analyses that supplement those required by QM. These include comprehensive end-use criteria and carbon pollutant reductions, while QM requires carbon, hydrocarbon, CO, and NO_x reduction benefits only. OTT Impacts also consider the fuel cycle carbon savings. QM benefits are limited to the end-use, fuel economy benefits.

The Economic Spreadsheet Model (ESM), a spreadsheet model that estimates employment impacts of OTT's programs, is described first. The next section describes the methodology for estimating vehicle infrastructure capital requirements. A preliminary model for estimating life cycle cost, EV capital and operating costs, is described in the next section. The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, an analytic tool for evaluating emissions of criteria pollutants and greenhouse gases also is summarized. The next section concerns criteria pollutant emissions reduction values. Finally, estimating reductions in carbon emissions from the commercial utilization of OTT-sponsored technologies is discussed.

5.1 Economic Benefit Estimates

The ESM is a spreadsheet model that estimates employment impacts of OTT's programs. The spreadsheet takes economic impacts from the quality metrics process and applies them to economic multipliers, developed with Department of Commerce data, to estimate employment impacts of OTT technologies. Key inputs to the model are:

1) incremental vehicle cost of OTT technologies (if any);
2) money spent on alternative fuels associated with OTT's technologies;
3) money saved from decreased spending on gasoline or diesel; and
4) projected costs savings for each technology.

Exhibit 5-1 shows a summary of job impacts by sector of the economy. The multipliers used to provide these numbers are industry specific at an aggregate level. The multipliers are derived from the Regional Input-Output Modeling System (RIMS II) developed by the Bureau of Economic Analysis (BEA), U.S. Department of Commerce. They are based on the 1992 industry structure for the U. S. as a whole and updated with 1995 regional data. A detailed analysis of how the multipliers were calculated in presented in Appendix C.

The multipliers are used to calculate net jobs and GDP by multiplying the multipliers against the spending flows associated with the advanced technologies, such as increased spending on vehicles; decreased spending on oil; fuel cost savings; and increased spending on alternative fuels. Exhibit 5-1 shows that the mining industry loses jobs while most other industries gain jobs. Advanced transportation technologies create jobs, in large part, because they induce spending in areas with larger multipliers than areas where spending would have occurred. The mining industry loses jobs because the reduced spending on oil affects the mining industry more than other industries. Job impacts attributable to the individual technologies fostered by OTT are indicated in Exhibit 5-2.

The increase in GDP is shown in Exhibit 5-3. Like the increase in jobs, the increase in GDP was calculated by applying the multipliers discussed above and in Appendix C. While the impact on GDP appears to be large, compared to the baseline, it represents an effect of less than one percent (1%).

Exhibit 5-1: Employment Impacts by Sector of Economy (Jobs)

Jobs by Industry	2000	2010	2020
Farm, forestry, and fishery products	115	11,848	34,315
Mining	-621	-39,029	-87,157
Construction	-17	-586	-2,543
Durable goods	451	66,718	87,836
Non-durable goods	181	19,624	40,704
Transportation and public utilities	128	12,248	22,431
Wholesale trade	140	16,298	27,345
Retail trade	430	10,745	44,339
Finance, insurance, & real estate	146	-525	12,718
Service	1,148	33,303	123,061
Private households	34	339	3,054
Total	2,135	130,982	306,104

Exhibit 5-2: Employment Impacts by Technology (Jobs)

Technology	2000	2010	2020
Alternative Fuel Vehicles	1,393	12,528	11,649
Biofuels	0	22,258	53,424
Electric Vehicle R&D	0	5,710	11,521
Fuel Cell R&D	0	2,728	33,965
Heavy Duty R&D	742	7,716	16,984
Hybrid Vehicle R&D	0	28,490	77,034
Light Duty Engine--car	0	14,697	34,593
Light Duty Engine--truck	0	21,298	29,354
SIDI	0	11,186	24,614
Lightweight Materials R&D	0	4,372	12,966
	2,135	130,982	306,104

Exhibit 5-3: GDP Increase (Millions of Dollars)

Technology	2000	2010	2020
Alternative Fuel Vehicles	$0	$1,974	$4,642
Biofuels	($3)	$682	$787
Electric Vehicle R&D	$0	$1,659	$887
Fuel Cell R&D	$0	$1,508	$2,814
Heavy Duty R&D	$22	($122)	($285)
Hybrid Vehicle R&D	$0	$2,481	$2,889
Light Duty Engine--car	$0	$2,152	$2,039
Light Duty Engine--truck	0	1553	1179
SIDI	0	2027	1480
Lightweight Materials R&D	$15	$367	$1,087
	$34	$14,281	$17,520

5.2 Vehicle Infrastructure Capital Requirements

This section describes the methodology for estimating vehicle infrastructure capital requirements. The basic methodology, rationale for production volume cost estimates, and capital constraints of auto manufacturers are addressed.

A rough estimate of capital investment necessary to produce advanced light vehicles was made. The methodology consists of three (3) steps:

1. Estimate vehicles sold per technology by year;
2. Estimate production facility costs on a volume basis by technology;
3. Apply the production facility cost factor to vehicle sales that exceed the sales in the previous year for each technology.

Step 1 is based on the vehicle choice model results--the vehicle choice model provides sales numbers by technology per year. Step 2 is from empirical data and is discussed in more detail below. Step 3 is a simple way to estimate the incremental costs--more sophisticated methods in the future are anticipated. In general it is anticipated that a minimum of 300,000 vehicle sales per year is required in order for the production of an alternative fuel vehicle to be sustained.

Production Facility Costs

To estimate production facility costs, some recent estimates to develop new car lines were reviewed. Examples used include (Refs. 15-21):

- Saturn production plant costs of $4.5 billion to produce 500,000 vehicles per year.
- Ford Contour costs to retool nine assembly plants for new model costing $6 billion to produce 700,000 per year.

- Various estimates of engine and transmission plants estimating costs of about $300 million to build facilities with production outputs of 100,000 engines/transmissions per year.
- A Congressional Research Service report estimating changeover costs (for producing more efficient vehicles and engine) of $1.5 billion to $3.0 billion per car line (250,000 to 300,000 vehicles per year).

Based on the above information, the following production infrastructure costs by type of vehicle were estimated:

- Advanced Diesel and SDI: $300 million per 100,000 vehicles. This cost is based primarily on cost to build a new engine plant. It is assumed that these technologies would be options for an existing production line.
- CNG Vehicles: $700 million per 100,000 vehicles. This cost is based on engine costs plus supporting fuel systems costs such as different tanks and fuel supply systems. It is assumed that CNG vehicles would be adapted from existing car lines.
- Electric, hybrid, and fuel cell vehicles: $2 billion per 100,000 vehicles. This cost is based on new assembly plant, engine, battery, motor, and supporting technology plant costs. It is assumed that these vehicles would be totally new car lines.

Exhibit 5-4 shows capital infrastructure costs associated with producing advanced automotive technologies. It shows that expenditures are greatest in 2008 at over 1.4 billion dollars, primarily due to production of hybrid vehicles. This table is reproduced from Appendix A, Table A-28.

Exhibit 5-5 shows a graphical presentation of the same information in comparison to baseline industry investment.

<u>Capital Constraints of Auto Manufacturers</u>

Exhibit 5-6 shows aggregate capital expenditures by the motor vehicle industry in the U.S. and expenditures by the major domestic manufacturers globally in billions of dollars for 1991 to 1997. The U.S. expenditures column includes expenditures by the major domestic manufacturers, transplants and parts suppliers. These figures give an indication of how constrained industry would be if they incurred capital infrastructure investment costs referred to in Exhibit 5-4.

Exhibit 5-4: Capital Infrastructure Costs
(Millions of 1996 Dollars)

Year	Advanced Diesel	CNG	Electric	Hybrid	Fuel Cell	Total
2000	$0	$9	$0	$0	$0	**$9**
2001	$0	$59	$0	$0	$0	**$59**
2002	$7	$49	$0	$0	$0	**$56**
2003	$73	$62	$16	$78	$0	**$229**
2004	$243	$26	$110	$390	$0	**$769**
2005	$256	$34	$144	$318	$0	**$752**
2006	$179	$1	$93	$467	$0	**$740**
2007	$101	$0	$146	$892	$33	**$1,172**
2008	$57	$0	$148	$1,006	$217	**$1,428**
2009	$16	$0	$85	$614	$220	**$935**
2010	$5	$0	$50	$0	$228	**$283**
2011	$0	$0	$0	$34	$239	**$273**
2012	$10	$0	$0	$257	$209	**$476**
2013	$3	$0	$0	$234	$34	**$271**
2014	$13	$0	$0	$257	$254	**$524**
2015	$10	$0	$0	$60	$253	**$323**
2016	$0	$0	$0	$0	$197	**$197**
2017	$0	$0	$0	$0	$20	**$20**
2018	$6	$0	$0	$16	$20	**$42**
2019	$10	$0	$0	$24	$10	**$44**
2020	$33	$0	$0	$88	$66	**$187**

Exhibit 5-5: Graph of Capital Costs

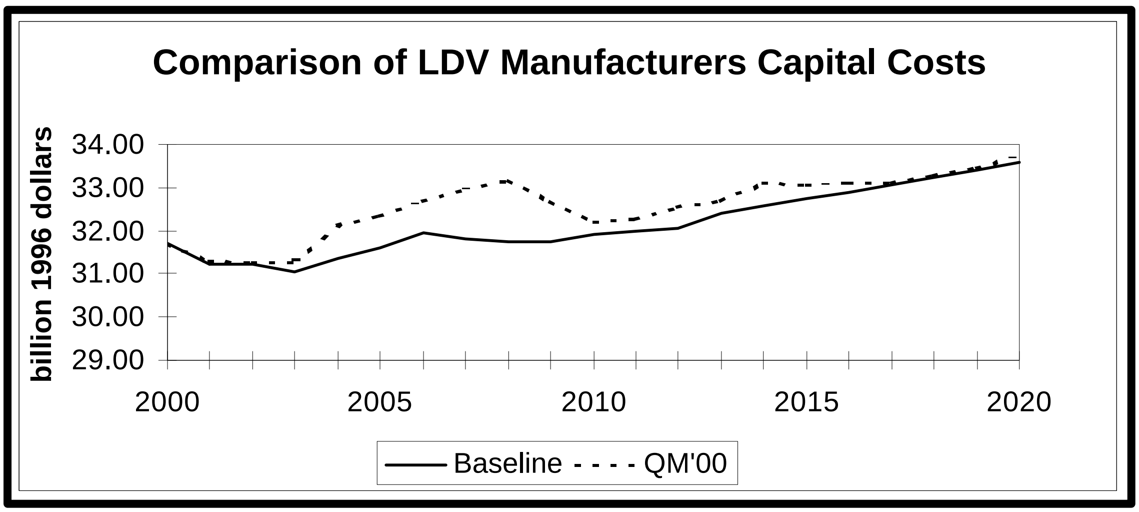


Exhibit 5-6: Aggregate Capital Expenditures
(billions of U.S. dollars)

YEAR	GM	Ford	Chrysler	TOTAL Big 3
1997	$10.1	$7.9	$5.0	**$23.0**
1996	$9.9	$8.2	$4.6	**$22.7**
1995	$9.0	$8.9	$3.7	**$21.6**
1994	$5.8	$8.7	$4.0	**$18.5**
1993	$5.6	$7.2	$3.2	**$16.0**
1992	$5.8	$6.3	$2.5	**$14.6**
1991	$6.6	$6.5	$2.5	**$15.6**

Our analysis indicates that in most years, the capital spending on production facilities would be less than $2 billion per year, which is substantially less than what the major domestic manufacturers have been spending on capital infrastructure. However, this may mean that other improvements may be deferred.

5.3 Life-Cycle Cost Effects

Argonne National Laboratory (ANL) has developed spreadsheet models for projecting hybrid electric and electric vehicle capital and operating costs. The methodologies summarized here and applied in the accompanying spreadsheet model are the results of work by Vyas et al., 1997 (Ref. 22); Cuenca and Gaines, 1997 (Ref. 23); and Cuenca, 1995 (Ref. 24) and 1996 (Ref. 25).

For electric vehicles, the cost projection model covers the two QM vehicle types in which electric technology competes: small car and passenger truck. The user can select one of these vehicle types. EV price, operating costs, and life-cycle costs for the selected vehicle type are calculated by the methodology. Prices and costs are projected for four points in time; years 2000, 2005, 2010, and 2020. The operating and life-cycle costs for the corresponding conventional vehicle for the four forecast years are also computed by using fuel price, fuel economy, and non-fuel cost information. Default values for data items are stored in separate worksheets and pertinent values are displayed for the user. The user is allowed to specify values different from the default values for most of the items.

The default prices for the corresponding conventional vehicle for the four forecast years are displayed which can be superseded by user specified prices. Gasoline price and conventional vehicle fuel economy and non-fuel operating costs are shown. Default values can be selected, or user-specified inputs can be utilized. The user can select one of the two motor types, induction or permanent magnet. Electricity rates and EV curb weights are displayed for the user to either accept or change. Energy consumption per mile (at the meter) and non-fuel operating costs are displayed and the user is allowed to specify values for each.

The model includes six battery types; lead acid, nickel metal hydride, lithium polymer, lithium ion, zinc air, and nickel cadmium. The default characteristics (specific power, specific energy, shelf life, cycle life, and unit cost) of the selected battery type are displayed, but the user may specify other characteristics. The methodology computes power requirements for the selected vehicle. Energy capacities of the selected battery that match the power requirements are computed and displayed. The energy for all or selected years may be increased with user-specified values. An increase in the energy capacity results in a bigger battery pack with higher mass and an increase in battery's contribution to vehicle operating cost. The methodology computes the contribution to vehicle price by converter and motor on the basis of the specified power.

The methodology uses published conventional vehicle cost information (Ref. 25). For electric vehicles, the costs of oil and filters are assumed as zero. This contributes to a maintenance cost that is assumed to be 20% of the cost for the conventional vehicle. Tire replacement costs are unchanged compared to conventional vehicles. Estimates of EV energy use per mile are a displayed result. In a more-generally applicable version of the model, these values are from the electric vehicles total energy cycle analysis (Ref. 23) while in the OTT version, these values are from the 1997 OTT Program Analysis Report (Ref. 26).

Battery replacement costs are computed by applying a methodology developed as a part of an ANL study (Ref. 27). Batteries are replaced at the end of shelf and cycle lives and the higher of these two costs is carried forward. Usually the cycle life cost is higher than the shelf life cost. If the battery lease option is selected then the cost of the first battery pack is excluded from the purchase price and included in the operating cost. A lease management fee is added in this case. The present value of the total cost of replacement batteries (cost of the first battery is a part of the vehicle price if the lease option is not selected) is distributed over the life-time miles of the vehicle. The methodology also computes lifetime costs for both the conventional and electric vehicles by distributing present values of their purchase prices and costs over their respective usage.

For hybrid electric vehicles (HEV), the cost projection model covers the two configurations: parallel and series (Ref. 25). Within each of these configurations the vehicles are separated into the three vehicle categories in which hybrid electric technology competes: small car, midsize car, and passenger truck. The user can select one of these configuration and categories. HEV price, operating costs, and life-cycle costs for the selected vehicle are calculated by the methodology. Prices and costs correspond to varying production levels. The operating and life-cycle costs for the corresponding conventional vehicle for the forecast year that relate to the production level are also computed using fuel price, fuel economy, and non-fuel cost information. Default values for data items are stored in separate worksheets and pertinent values are displayed for the user. The user is allowed to specify values different from the default values for most of the items.

The default prices of the corresponding conventional vehicles can be superseded by user-specified prices. Gasoline prices and conventional vehicle fuel economy and non-fuel operating costs are shown. Default values can be selected or user-specified inputs can be utilized.

HEV selection including fuel economy, construction material usage, curb weight, performance, power values are shown. The indicated default values can be selected or user-specified inputs can be utilized. The combustion engine portion of the powerplant can be chosen as either gasoline or diesel type. On the electrical portion of the powerplant, the user can select from three motor/generator types of: permanent magnet, induction, or switched reluctance. Battery choices include lead acid, nickel metal hydride, and lithium ion. If the default choice of lead acid is chosen for the battery the user may chose to accept the displayed default values for specific power, specific energy, battery cost, shelf life, cycle life, energy capacity, and energy consumption rates or can enter user-specified values. The methodology computes the power requirements for the selected vehicle with the default values of battery energy capacity shown to match the selected battery. The methodology computes the contribution to vehicle price by converter and motor on the basis of the specified power. Options to include a separate generator and to provide a connection to the electrical grid are available for the user to chose.

The methodology uses published conventional vehicle cost information (Ref. 27). Tire replacement costs are unchanged compared to conventional vehicles. The HEV costs are allocated to the various subsystems of the vehicle: auxiliary power system (with combustion engine, electronics and emissions control, cooling, exhaust with catalyst, and fuel storage and distribution), motor/generator system, and transmission. Data from an earlier ANL project is used to determine the costs of the auxiliary power subsystem (Ref. 25). Another ANL project provided data for the motor/generator system (Ref. 24). The greater complexity of the transmission required for the parallel powerplant arrangement results in a higher cost than the parallel arrangement. The cycle life of the lead acid batteries is decreased 30 % from EV use due to the nature of HEV operation.

Battery costs for the HEV are assumed to be 20 % greater than in EV due to their high-power-low-energy design requiring more precise manufacturing of the electrodes. Battery packs are replaced at the end of their shelf life or cycle life, whichever is shorter. Both shelf life and cycle life are used to compute the cost of batteries with the greater cost used.

To date the model has been used as a comparison point to OTT program cost goals. The model is being expanded to include hybrid electric vehicles, and will be considered as a tool for future OTT impacts assessments.

5.4 Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model

GREET was developed to be used as an analytic tool for evaluating emissions of criteria pollutants and greenhouse gases, energy use, and petroleum consumption of various vehicle technologies on a full fuel-cycle basis (Ref. 28). For a given transportation fuel, a fuel cycle covers the processes from energy feedstock (or primary energy) production to on-vehicle combustion of fuel. In particular, these stages are included in a fuel cycle:

- Energy feedstock production;
- Feedstock transportation and storage;
- Fuel (or energy product) production;
- Fuel transportation, storage, and distribution; and
- Vehicular fuel combustion.

The GREET model consists of three elements:

- Light vehicles (current version 1.4)
- Light vehicle materials (current version 2.4), and
- Heavy vehicles (current version 3.4).

Exhibit 5-7 lists the Carbon Coefficients for the different fuels. These coefficients are used in the Appendix A Table A-17, "Total Carbon Emissions Reductions" to calculate the reduction in carbon emissions each year to 2020 due to the market penetration of the advanced vehicle technologies.

Exhibit 5-7: Carbon Coefficients

Fuel	Coefficient, MMT/Quad
Gasoline	19.41
Diesel	19.95
CNG	14.47
LPG	17.16
Ethanol	0.5823
Electric Utilities	22.32

DOE/EIA-0573, Emissions of Greenhouse Gases in the United States, Table 6, P. 15

GREET includes sixteen (16) fuel cycles. Among them, four (4) are petroleum-based cycles: petroleum to conventional gasoline, petroleum to RFG; petroleum to diesel; and petroleum to LPG. Seven (7) cycles are natural gas (NG)-based: NG to CNG; NG to liquefied natural gas (LNG); NG to LPG; NG to methanol; NG to dimethyl ether; NG to hydrogen; and NG to Fischer Tropsche diesel. Three (3) cycles are ethanol production cycles: corn to ethanol; woody biomass to ethanol; and herbaceous biomass to ethanol. The remaining two (2) cycles are soybean to biodiesel, and solar energy to hydrogen.

GREET was developed for estimating emissions and energy use of light and heavy vehicles (i.e., passenger cars, light, medium, and heavy trucks, and buses). The advanced and conventional technologies included are: electric vehicles; hybrid vehicles; fuel cell vehicles operating on hydrogen or methanol; CNG vehicles; LPG vehicles; and internal combustion engine vehicles fueled with RFG, low-sulfur diesel, M85, M100, E85, or E100. Fuel cycle grams per mile emissions and Btu per mile energy use are calculated for each vehicle type.

GREET calculates the energy consumption of a fuel cycle by taking into account the amount of energy consumed in each of the stages involved in the fuel cycle. In addition, by considering petroleum consumption in each fuel-cycle stage, the model calculates petroleum use by different vehicle types using different fuels.

Calculation of emissions for a particular stage are estimated in grams per million Btu of fuel throughput from the stage. The calculation of emissions takes into account combustion of process fuels, leakage of fuels, fuel evaporation, and other emission sources.

Outputs resulting from GREET include the following:

- Grams per mile emissions for HC, CO NO_x, PM_{10}, and SO_x;
- Grams per mile emissions for CO_2, CH_4, and N_2O;

- Global warming potential weighted greenhouse gas emissions;
- Btu per mile fuel-cycle energy consumption; and
- Btu per mile fuel-cycle petroleum consumption.

5.5 Costs of Various Pollutants

The criteria pollutant emissions reduction values were calculated using an EPA estimate developed in 1990 which sets the costs of environmental controls at $360/ton for CO, $3660/ton for HC and $3300/ton for NO_x (Ref. 29). Costs in Reference 30 were modified to reflect 1996 dollars.

Various CO_2 control cost estimates are indicated in Exhibit 5-8. Control costs are used instead of damage costs due to the great difficulty of calculating damage costs. These costs represent the "value" of reducing CO_2 emissions.

For the QM 99 evaluations, a low-end value of **$15/metric ton (tonne) of CO_2** reduction was utilized. This **equates to $55/metric ton of Carbon reduced**. Note that the QM benefit values (carbon reduction) relate to fuel economy/conservation effects only. The OTT impacts analysis consider the total fuel cycle benefits.

5.6 Aggregate Environmental and Economic Benefits Estimates

The OTT Program Analysis Methodology includes estimating reductions in carbon emissions from the commercial utilization of OTT-sponsored technologies. Exhibit 5-9 details carbon emission reductions estimated by technology. By 2020, the OTT program impact will reduce carbon emissions by nearly 12 percent (12%).

Exhibit 5-8: Range of Costs to Control CO_2 Emissions

Study	Year	Reported Value ($/MMTCE)		$1996 Value ($/MMTCE)	Notes
Costs of Tree Planting Used as a Reasonable First Approximation					
Buchanan (Bonneville Power Adm.)	1988	Low High	$17.08 $47.44	$22 $61	
Dudek and LeBlanc (EDF)	1990	Low High	$53 $58	$63 $69	
Chernick and Caverhill	1989	Low High	$80 $120	$99 $149	
Carbon Tax Required to Meet Stated Levels					
EMF 12 (1990 levels)	1992	Low High	$15 $150	$17 $165	Summary of 10 models
EMF 12 (10% below 1990 levels)	1992	Low High	$35 $200	$39 $220	Summary of 10 models
EMF 12 (20% below 1990 levels)	1992	Low High	$50 $330	$55 $363	Summary of 10 models
AFL-CIO (1990 levels)	1997		$100	$100	Congressional testimony
David Montgomery (Charles R. Assoc.)	1997	Low High	$150 $200	$150 $200	Congressional testimony
DOE/EIA (7% below 1990 levels)	1998		$348	$348	"Carbon price" for 2010
DOE/EIA (3% below 1990 levels)	1998		$294	$294	"Carbon price" for 2010
DOE/EIA (1990 levels)	1998		$250	$250	"Carbon price" for 2010
DOE/EIA (9% over 1990 levels)	1998		$163	$163	"Carbon price" for 2010
DOE/EIA (14% over 1990 levels)	1998		$134	$134	"Carbon price" for 2010
DOE/EIA (24% over 1990 levels)	1998		$67	$67	"Carbon price" for 2010
Cost of Emission Allowances under a Trading System					
Clinton Administration (domestic only)	1998		$200	$196	The Oil Daily, 8/4/98
Clinton Administration (global trading)	1998		$14	$13.72	The Oil Daily, 8/4/98
Cecil Roberts(UMWA)	1998 1998		$100 $200	$98 $196	Assumes global trading; JI; etc. No global trading
Optimal Tax (taking into account projected damage)					
Peck and Tiesberg	1992	Low High	$8 $210	$9 $231	Lower value is for 1990 Higher value is for 2200
Maddison	1993		$16.84	$18	Tax for 2000
Nordhaus	1993		$5.24	$6	
Williams	1995		$0	$0	
Damage Estimates for Marginal Emissions					
Fankhauser and Pearce	1993	Low High	$5 $25	$5 $27	
Hope and Maul	1996	Low High	$5 $29	$5 $29	Mean value of initial scenario Mean value for scenario w/ highest cost
Proposed Externality Values					
California	1990		$29	$35	Proposed value for resource planning
Massachusetts	1990		$92	$109	Proposed value for resource planning
New York	1990		$5	$6	Proposed value for resource planning
Nevada	1990		$61	$73	Proposed value for resource planning
EPA (*Renewable Electricity Generation*)	1992	Low High	$50 $150	$55 $165	Values used for modelling purposes
Miscellaneous					
Ledbetter and Ross (ACEEE)	1990		$176	$209	Based on gas tax needed to raise CAFE to 44 mpg

Exhibit 5-9: Carbon Emissions Reductions

Technology	Carbon Reductions Million Metric Tons Eqiuvalent (MMTCE)		
	Year 2000	Year 2010	Year 2020
Technology Deployment	0.267	1.817	1.942
Fuels Development (Bio-fuels)	0.000	6.774	18.836
Flex-Fuel	0.000	0.402	1.314
Dedicated	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000
Blends & Extenders	0.000	6.372	17.522
Advanced Automotive Technology	0.000	12.115	30.534
Electric Vehicle R&D	0.000	0.289	0.728
Fuel Cell Vehicle R&D	0.000	0.511	4.692
Hybrid Vehicle R&D	0.000	5.245	13.815
SDI	0.000	2.137	4.444
Light Vehicle Engine R&D	0.000	3.933	6.855
Heavy Vehicle R&D	0.175	3.869	7.480
Classes 1&2	0.000	2.216	3.756
Classes 3-8	0.175	1.653	3.724
Advanced Materials	0.000	0.237	0.987
Propulsion System	0.000	0.000	0.000
Light Vehicle	0.000	0.237	0.987
Electric Vehicle	0.000	0.028	0.070
Hybrid Vehicle	0.000	0.153	0.402
Fuel Cell Vehicle	0.000	0.056	0.515
Heavy Vehicle	0.000	0.000	0.000
Total	0.442	24.812	59.779
Baseline (Total Transportation)	491.8	552.4	591.0
Percent Reduction	0.1%	4.5%	10.1%

Emissions reductions for NO_x, CO, and HC also are evaluated. Total emissions reductions and values for NO_x, CO and HC are found in Tables A19 – A24 in Appendix A.

6.0 Benefit/Cost Analysis and Accomplishments

Exhibit 6-1 provides a summary of all costs and benefits associated with OTT's QM 2000 estimates in cumulative terms. The benefits-cost table summarizes the benefits and costs of OTT's technologies. Costs include DOE Budgets, incremental vehicle costs to consumers, industry investment, and the induced increase in natural gas prices. The benefits consist of energy cost savings, oil security benefits, "gasoline, distillate, and residual price decreases," the value of reducing CO_2, CO, HCs, and NO_x, and the increase in GDP.

Costs

The budget cost is the estimated OTT budget through 2013.

The incremental costs are the costs incurred by consumers by choosing an advanced technology over a conventional technology. It is the difference between the advanced technology cost and the conventional cost. Industry investment represents the additional cost that would be incurred by the automotive industry in the infrastructure necessary to produce the alternative vehicles. This cost is in addition to projected investment levels that would be anticipated with conventional technology.

Benefits

Energy cost savings are the reduced energy costs of operating advanced vehicles compared to the cost of conventional vehicles; it is the difference between the operating costs of conventional vehicles and advanced vehicles.

The benefits of energy security were conservatively estimated at $5 per barrel based on a number of estimates presented in Exhibit 4-5.

Some increase in natural gas prices can be expected to occur due to the increase in demand from alternative fuel vehicles. However, it was assumed that the aggregate effect of a reduction in world and domestic oil prices due to conservation and substitution from the advanced technologies would offset the aggregate effect of a natural gas price rise.

The value of reducing CO_2, CO, HCs, and NO_x was estimated by multiplying the tons of the pollutant reduced by OTT technologies, by the value of reducing the pollutant. To determine the value of reducing the pollutants, OTT used estimates from EPA for a National Energy Strategy exercise. For CO_2, OTT used an estimate based on a number of studies presented in Exhibit 5-8.

The increase in GDP was estimated by the Economic Spreadsheet Model discussed in Section 5.1.

Benefit to cost ratios are shown at the bottom of Exhibit 6-1. The years 2010 and 2020, with ratios of 50.19 and 96.51, respectively, which indicate the significance of OTT's programs. (The values do not consider discounting effect.)

More results of the QM 2000 analysis can be found in the Appendix A.

Exhibit 6-1: Benefit-Cost Table From the Societal Perspective (Million $, 1996)

Item	2005	2010	2015	2020
Costs				
Budget Costs	$1,250	$2,500	$3,250	$3,250
Total	$1,250	$2,500	$3,250	$3,250
Energy (Table A-15)				
Energy Savings	$2,620	$30,790	$98,120	$192,790
Benefit-Cost - Energy	**2.10**	**12.32**	**30.19**	**59.32**
Environment (Tables A-18, 20, 22, 24)				
Carbon ($55 per tonne C)	$647	$5,064	$15,679	$30,878
NOX ($3,300 per tonne)	$15	$99	($85)	($697)
CO ($360 per tonne)	$174	$2,163	$8,100	$17,578
HC ($3,660 per tonne)	$757	$4,234	$11,765	$21,640
Total - Environment	$1,593	$11,560	$35,459	$69,399
Benefit-Cost - Environment	**1.27**	**4.62**	**10.91**	**21.35**
Economy (Tables A-27, 28)				
Incremental Costs	($10,367)	($63,994)	($131,660)	($208,293)
Capital Investment	($1,875)	($6,431)	($8,390)	($8,790)
GDP Benefits	$14,417	$78,733	$154,996	$239,357
Total - Economy	$2,175	$8,308	$14,946	$22,274
Benefit-Cost - Economy	**1.74**	**3.32**	**4.60**	**6.85**
Security (Table A-10)				
Oil Security ($5/bbl)	$183	$2,190	$7,300	$14,600
Military Costs ($5/bbl)	$183	$2,190	$7,300	$14,600
Total - Security	$365	$4,380	$14,600	$29,200
Benefit-Cost - Security	**0.29**	**1.75**	**4.49**	**8.98**
Total Benefits	**$ 6,753**	**$ 55,038**	**$ 163,125**	**$ 313,663**
Cumulative Benefit-Cost Ratio: Energy	**2.10**	**12.32**	**30.19**	**59.32**
Cumulative Benefit-Cost Ratio: Energy, Environment	**3.37**	**16.94**	**41.10**	**80.67**
Cumulative Benefit-Cost Ratio: Energy, Environment, Economy	**5.11**	**20.26**	**45.70**	**87.53**
Cumulative Benefit-Cost Ratio: Energy, Environment, Economy, Security	**5.40**	**22.02**	**50.19**	**96.51**

Three principal changes were made in the Quality Metrics calculations compared to the preceding year. These modifications contributed to the changes in oil savings and other program benefits:

1. The EIA AEO 98 base case fuel prices were lower than the base case in AEO 97. The lower fuel prices had the major influence on altering benefits estimates.

2. Changes in the technology input assumptions. For example, the SIDI engine option was added to all light vehicle classes. Two vehicle classes (SUV and Minivan) were separated this year, whereas they were combined before.
3. A new set of coefficients for the vehicle choice model was calibrated based on a sample of the U.S. population. Earlier coefficients were based on respondents from California only.

Also, the oil savings for the Technology Utilization planning unit are based on the level of natural gas use in light vehicles. These vehicles have a much lower market penetration in this year's projection than in prior years.

Analytical improvements to this year's analyses include the following:

- Developed a uniform set of consumer choice coefficients for use by EIA and OTT for the purchase of household light vehicles.
- Expand the medium and heavy vehicle market characterizations by the inclusion of hybrid vehicles in Classes 3-6.
- Continued the development of vehicle purchase and life-cycle cost assessments, and the interpretation of life-cycle cost as a consumer preference issue. Refined the EV cost model and developed an analogous model for HEV costs. The capital cost investment and cost to achieve carbon reductions also were updated.
- Analysis of the economic impacts of investment in advanced vehicle transportation technologies was updated and expanded.

6.1 Comments and Future Improvements

This methodology can be improved in a number of ways. Following is a list of issues that will be considered in future methodology upgrades.

- Update the analysis to reflect AEO 99 baseline scenario and prices.
- Review the estimates of technology utilization levels due to EPACT and other mandated programs based on the pending assessment of oil displacement goals under Section 504.
- Assess the impacts on technology market penetrations of EPA changes in Ozone and Particulate (PM 2.5) standards.
- Continue monitoring light vehicle fuel economy trends and projections to refine conventional vehicle performance characteristics.
- Expand the alternative fuels analysis to consider the supply and use of hydrogen and other appropriate fuels and resources.
- Revisit infrastructure production cost factors. Peer review the factors and methodology. Investigate how infrastructure costs are handled in EIA's NEMS model and in the IDEAS model.
- Extend analysis period to the year 2030.

TABLE A-1 QM '00 SUMMARY

PLANNING UNIT	Primary Energy Displaced (quads) 2000	2005	2010	2020	Primary Oil Displaced (quads) 2000	2005	2010	2020	Energy Cost Savings (billions of 1995 $'s) 2000	2005	2010	2020	Carbon Reductions (MMtons) 2000	2005	2010	2020
Technology Utilization	**0.000**	**0.000**	**0.000**	**0.000**	**0.066**	**0.289**	**0.414**	**0.441**	**0.126**	**0.711**	**0.850**	**0.697**	**0.267**	**1.243**	**1.817**	**1.942**
Fuels Development	**0.000**	**0.051**	**0.360**	**1.001**	**0.000**	**0.051**	**0.360**	**1.001**	**0.000**	**-0.005**	**-0.001**	**0.073**	**0.000**	**1.020**	**6.774**	**18.836**
Flex-Fuel	0.000	0.000	0.021	0.070	0.000	0.000	0.021	0.070	0.000	-0.005	-0.001	0.073	0.000	0.064	0.402	1.314
Dedicated	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Blends and Extenders	0.000	0.051	0.339	0.931	0.000	0.051	0.339	0.931	0.000	0.000	0.000	0.000	0.000	0.956	6.372	17.522
Advanced Automotive Technologies	**0.000**	**0.032**	**0.639**	**1.589**	**0.003**	**0.109**	**0.784**	**1.835**	**0.000**	**1.063**	**6.109**	**16.417**	**0.000**	**1.505**	**12.115**	**30.533**
Electric Vehicle R&D	0.000	0.002	0.012	0.019	0.003	0.051	0.157	0.266	0.000	0.067	0.516	0.970	0.000	0.031	0.289	0.728
Fuel Cell R&D	0.000	0.000	0.027	0.246	0.000	0.000	0.027	0.246	0.000	0.000	0.273	2.520	0.000	0.000	0.511	4.692
Hybrid Vehicle R&D	0.000	0.021	0.270	0.712	0.000	0.001	0.270	0.712	0.000	0.215	2.749	7.288	0.000	0.414	5.245	13.815
SDI	0.000	0.008	0.110	0.229	0.000	0.008	0.110	0.229	0.000	0.086	1.120	2.345	0.000	0.167	2.137	4.444
Light Duty Engine R&D	0.000	0.000	0.220	0.383	0.000	0.049	0.220	0.383	0.000	0.696	1.451	3.294	0.000	0.893	3.933	6.855
Heavy Vehicle Technologies	**0.006**	**0.066**	**0.203**	**0.227**	**0.008**	**0.068**	**0.205**	**0.396**	**0.068**	**0.407**	**2.750**	**4.337**	**0.175**	**1.293**	**3.869**	**7.480**
Classes 1&2	0.000	0.023	0.123	0.210	0.000	0.023	0.123	0.210	0.000	0.036	2.040	2.773	0.000	0.410	2.216	3.756
Classes 3-8	0.006	0.042	0.080	0.017	0.008	0.044	0.083	0.186	0.068	0.371	0.710	1.564	0.175	0.883	1.653	3.724
Advanced Materials	**0.000**	**0.001**	**0.012**	**0.050**	**0.000**	**0.006**	**0.026**	**0.073**	**0.000**	**0.013**	**0.160**	**0.583**	**0.000**	**0.015**	**0.237**	**0.988**
Propulsion System Materials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Light Vehicle Materials	0.000	0.001	0.012	0.050	0.000	0.006	0.026	0.073	0.000	0.013	0.160	0.583	0.000	0.015	0.237	0.988
Electric Vehicle	*0.000*	*0.000*	*0.001*	*0.002*	*0.000*	*0.005*	*0.015*	*0.026*	*0.000*	*0.006*	*0.050*	*0.094*	*0.000*	*0.003*	*0.028*	*0.070*
Hybrid Vehicle	*0.000*	*0.001*	*0.008*	*0.021*	*0.000*	*0.001*	*0.008*	*0.021*	*0.000*	*0.006*	*0.080*	*0.212*	*0.000*	*0.012*	*0.153*	*0.402*
Fuel Cell Vehicle	*0.000*	*0.000*	*0.003*	*0.027*	*0.000*	*0.000*	*0.003*	*0.027*	*0.000*	*0.000*	*0.030*	*0.277*	*0.000*	*0.000*	*0.056*	*0.515*
Heavy Vehicle Materials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	**0.006**	**0.149**	**1.214**	**2.866**	**0.078**	**0.523**	**1.789**	**3.747**	**0.194**	**2.188**	**9.868**	**22.107**	**0.442**	**5.076**	**24.812**	**59.779**

PLANNING UNIT	MMB/D 2000	2005	2010	2020	MMB/D 2000	2005	2010	2020
Technology Utilization	**0.000**	**0.000**	**0.000**	**0.000**	**0.031**	**0.137**	**0.196**	**0.208**
Fuels Development	**0.000**	**0.024**	**0.170**	**0.473**	**0.000**	**0.024**	**0.170**	**0.473**
Flex-Fuel	0.000	0.000	0.010	0.033	0.000	0.000	0.010	0.033
Dedicated	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Blends and Extenders	0.000	0.024	0.160	0.440	0.000	0.024	0.160	0.440
Advanced Automotive Technologies	**0.000**	**0.015**	**0.302**	**0.751**	**0.001**	**0.061**	**0.370**	**0.867**
Electric Vehicle R&D	0.000	0.001	0.005	0.009	0.001	0.024	0.074	0.126
Fuel Cell R&D	0.000	0.000	0.013	0.116	0.000	0.000	0.013	0.116
Hybrid Vehicle R&D	0.000	0.010	0.128	0.336	0.000	0.010	0.128	0.336
SDI	0.000	0.004	0.052	0.108	0.000	0.004	0.052	0.108
Light Duty Engine R&D	0.000	0.000	0.104	0.181	0.000	0.023	0.104	0.181
Advanced Heavy Duty	**0.003**	**0.031**	**0.096**	**0.107**	**0.004**	**0.032**	**0.097**	**0.187**
Classes 1&2	0.000	0.011	0.058	0.099	0.000	0.011	0.058	0.099
Classes 3-8	0.003	0.020	0.038	0.008	0.004	0.021	0.039	0.088
Advanced Materials	**0.000**	**0.000**	**0.006**	**0.023**	**0.000**	**0.003**	**0.012**	**0.035**
Propulsion System Materials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Light Vehicle Materials	0.000	0.000	0.006	0.023	0.000	0.003	0.012	0.035
Electric Vehicle	*0.000*	*0.000*	*0.001*	*0.001*	*0.000*	*0.002*	*0.007*	*0.012*
Hybrid Vehicle	*0.000*	*0.000*	*0.004*	*0.010*	*0.000*	*0.000*	*0.004*	*0.010*
Fuel Cell Vehicle	*0.000*	*0.000*	*0.001*	*0.013*	*0.000*	*0.000*	*0.001*	*0.013*
Heavy Vehicle Materials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	**0.003**	**0.070**	**0.573**	**1.354**	**0.037**	**0.257**	**0.845**	**1.770**

									0.901 f											
									0.9717 h				-0.033	-0.338	-0.55	-0.892				
									0.912 e								2.735			
Electric Vehicle R&D	0.000	0.001	0.006	0.010	0.002	0.027	0.081	0.138	0	0.073	0.566	1.064	-0.112	-0.173	-0.527	-0.895				
Fuel Cell R&D	0.000	0.000	0.014	0.129	0.000	0.000	0.014	0.129	0.000	0.000	0.303	2.797					0.000	0.000		
Hybrid Vehicle R&D	0.000	0.010	0.131	0.346	0.000	0.010	0.131	0.346	0	0.221	2.829	7.5								
	1.400	1.327	1.329	1.336																
	0.000	0.010	0.030	0.060																
	0.000	0.013	0.040	0.080													1.000	1.000		
		-0.003	-0.010	-0.020													0.567	5.207		
				ZEV	0.0033	0.0457	0.0892	0.1433									0.000	0.034	0.317	0.798
					0.001559	0.021589	0.042138	0.067695									0.000	0.426	5.398	14.217

Note:

1) Advanced Materials - metrics shown for Light Vehicle Materials are derived from percentages of total metrics estimated for Electric, Hybrid and Fuel Cell vehicles
Electric: 8.8% of total
Hybrid: 2.8% of total
Fuel Cell 9.9% of total

2) Technology Utilization includes EPAct mandated fleet vehicles and household CNG vehicles.

3) Advanced Automotive Technologies Electric Vehice R&D includes ZEV mandates.

TABLE A-2 OTT QM'99 Planning Unit Estimates

Total Fossil Energy Savings Estimates
(Quadrillion Btu/Year)

Planning Unit	2000	2010	2020
Technology Utilization	0.07	0.41	0.44
Fuels Development	0.00	0.36	1.00
Advanced Automotive Tech	0.00	0.78	1.84
Heavy Vehicle Technologies	0.01	0.21	0.40
Materials Technologies	0.00	0.03	0.07
TOTAL	0.08	1.79	3.75

Total Energy Savings Estimates
(Quadrillion Btu/Year)

Planning Unit	2000	2010	2020
Technology Utilization	0.00	0.00	0.00
Fuels Development	0.00	0.36	1.00
Advanced Automotive Tech	0.00	0.64	1.59
Heavy Vehicle Technologies	0.01	0.20	0.23
Materials Technologies	0.00	0.01	0.05
TOTAL	0.01	1.21	2.87

Total Energy Cost Savings Estimates
(Billion 1996 $/Year)

Planning Unit	2000	2010	2020
Technology Utilization	0.13	0.85	0.70
Fuels Development	0.00	0.00	0.07
Advanced Automotive Tech	0.00	6.11	16.42
Heavy Vehicle Technologies	0.07	2.75	4.34
Materials Technologies	0.00	0.16	0.58
TOTAL	0.19	9.87	22.11

Total Carbon Equivalent Emissions Savings
(Million Metric Tons of Carbon/Year)

Planning Unit	2000	2010	2020
Technology Utilization	0.27	1.82	1.94
Fuels Development	0.00	6.77	18.84
Advanced Automotive Tech	0.00	12.12	30.53
Heavy Vehicle Technologies	0.18	3.87	7.48
Materials Technologies	0.00	0.24	0.99
TOTAL	0.44	24.81	59.78

TABLE A-4 Light Duty Vehicle Market Penetration

Year	Conventional	Advanced Diesel	Alcohol Flex	SDI	CNG	Electric	Hybrid	Fuel Cell
2000	96.58%	0.0%	3.34%	0.00%	0.08%	0.00%	0.00%	0.00%
2001	94.08%	0.0%	5.30%	0.00%	0.62%	0.00%	0.00%	0.00%
2002	92.29%	0.2%	6.49%	0.00%	1.07%	0.00%	0.00%	0.00%
2003	90.08%	1.7%	6.26%	0.00%	1.64%	0.05%	0.25%	0.00%
2004	82.88%	6.9%	5.92%	0.58%	1.86%	0.40%	1.49%	0.00%
2005	72.13%	12.2%	4.76%	5.38%	2.16%	0.86%	2.49%	0.00%
2006	63.03%	15.8%	4.80%	9.16%	2.14%	1.14%	3.92%	0.00%
2007	54.07%	18.0%	4.54%	12.88%	2.06%	1.60%	6.74%	0.10%
2008	44.50%	19.2%	4.58%	16.86%	2.03%	2.07%	9.93%	0.79%
2009	37.79%	19.6%	4.61%	20.34%	2.02%	2.34%	11.86%	1.48%
2010	37.24%	19.5%	4.60%	20.23%	2.01%	2.48%	11.70%	2.19%
2011	38.00%	19.2%	4.54%	19.42%	1.89%	2.27%	11.79%	2.93%
2012	36.52%	19.7%	4.46%	19.16%	1.85%	2.20%	12.56%	3.57%
2013	36.92%	19.5%	4.39%	18.54%	1.77%	2.05%	13.15%	3.64%
2014	35.45%	19.7%	4.35%	18.44%	1.76%	2.01%	13.88%	4.40%
2015	34.76%	19.8%	4.31%	18.37%	1.63%	1.97%	13.99%	5.15%
2016	35.27%	19.5%	4.16%	18.03%	1.62%	1.89%	13.83%	5.73%
2017	35.28%	19.6%	4.13%	17.99%	1.61%	1.86%	13.82%	5.76%
2018	35.27%	19.6%	4.09%	17.96%	1.60%	1.83%	13.82%	5.79%
2019	35.28%	19.7%	4.06%	17.90%	1.60%	1.81%	13.82%	5.79%
2020	34.11%	20.3%	4.11%	18.10%	1.59%	1.82%	14.02%	5.96%

Ref. VSCC Model

TABLE A-5 Light Duty Market Penetration Within Size Class

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
Conventional	96.6%	94.1%	92.3%	90.1%	82.9%	72.1%	63.0%	54.1%	44.5%	37.8%	37.2%	38.0%	36.5%	36.9%	35.4%	34.8%	34.1%
Flex Alcohol	3.3%	5.3%	6.5%	6.3%	5.9%	4.8%	4.8%	4.5%	4.6%	4.6%	4.6%	4.5%	4.5%	4.4%	4.3%	4.3%	4.1%
SDI	0.0%	0.0%	0.0%	0.0%	0.6%	5.4%	9.2%	12.9%	16.9%	20.3%	20.2%	19.4%	19.2%	18.5%	18.4%	18.4%	18.1%
Advanced Diesel	0.0%	0.0%	0.2%	1.7%	6.9%	12.2%	15.8%	18.0%	19.2%	19.6%	19.5%	19.2%	19.7%	19.5%	19.7%	19.8%	20.3%
CNG Dedicated	0.1%	0.6%	1.1%	1.6%	1.9%	2.2%	2.1%	2.1%	2.0%	2.0%	2.0%	1.9%	1.9%	1.8%	1.8%	1.6%	1.6%
Electric	0.0%	0.0%	0.0%	0.1%	0.4%	0.9%	1.1%	1.6%	2.1%	2.3%	2.5%	2.3%	2.2%	2.0%	2.0%	2.0%	1.8%
Hybrid	0.0%	0.0%	0.0%	0.3%	1.5%	2.5%	3.9%	6.7%	9.9%	11.9%	11.7%	11.8%	12.6%	13.2%	13.9%	14.0%	14.0%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.8%	1.5%	2.2%	2.9%	3.6%	3.6%	4.4%	5.2%	6.0%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
SIZE CLASS SHARES																	
Small Car	32.5%	32.4%	32.3%	32.2%	32.1%	32.0%	31.6%	31.2%	30.8%	30.4%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%
Large Car	24.1%	23.9%	23.7%	23.4%	23.2%	23.0%	22.8%	22.6%	22.4%	22.2%	22.0%	22.0%	22.0%	22.0%	22.0%	22.0%	22.0%
Minivan	11.2%	11.3%	11.3%	11.4%	11.4%	11.5%	11.6%	11.7%	11.8%	11.9%	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%
SUV	11.2%	11.3%	11.3%	11.4%	11.4%	11.5%	11.6%	11.7%	11.8%	11.9%	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%
Cargo Truck	21.0%	21.2%	21.4%	21.6%	21.8%	22.0%	22.4%	22.8%	23.2%	23.6%	24.0%	24.0%	24.0%	24.0%	24.0%	24.0%	24.0%
SMALL CAR																	
Conventional	100.0%	100.0%	100.0%	98.2%	83.7%	64.1%	57.0%	44.6%	32.3%	22.1%	21.9%	21.8%	21.5%	21.4%	21.3%	21.3%	21.0%
Flex Alcohol	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SDI	0.0%	0.0%	0.0%	0.0%	0.8%	6.0%	8.7%	12.6%	16.4%	19.6%	19.4%	19.2%	18.9%	18.7%	18.5%	18.4%	17.8%
Advanced Diesel	0.0%	0.0%	0.0%	1.6%	14.6%	28.0%	31.3%	31.4%	31.4%	31.4%	31.5%	31.9%	32.9%	33.4%	33.8%	34.2%	35.6%
CNG Dedicated	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electric	0.0%	0.0%	0.0%	0.2%	1.0%	2.0%	2.4%	3.4%	4.4%	4.7%	5.0%	4.9%	4.8%	4.7%	4.6%	4.5%	4.2%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	8.1%	15.5%	22.2%	22.2%	22.2%	22.0%	21.8%	21.7%	21.7%	21.4%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
LARGE CAR																	
Conventional	90.6%	85.4%	80.1%	83.1%	80.4%	72.9%	59.5%	53.6%	40.0%	34.1%	31.1%	27.9%	25.2%	25.3%	25.3%	25.3%	25.3%
Flex Alcohol	9.2%	13.3%	17.4%	13.4%	10.0%	8.6%	8.4%	7.0%	6.9%	6.8%	6.7%	6.6%	6.5%	6.4%	6.3%	6.3%	6.0%
SDI	0.0%	0.0%	0.0%	0.0%	0.7%	4.7%	8.7%	10.8%	14.1%	17.0%	17.0%	16.9%	16.7%	16.6%	16.6%	16.6%	16.5%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	4.5%	7.3%	10.4%	10.4%	10.4%	10.4%	10.7%	10.8%	10.9%	10.9%	11.0%
CNG Dedicated	0.2%	1.3%	2.5%	2.4%	2.5%	2.7%	2.6%	2.2%	2.1%	2.1%	2.0%	2.0%	2.0%	2.0%	2.0%	1.9%	1.9%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hybrid	0.0%	0.0%	0.0%	1.1%	6.4%	10.8%	16.3%	18.7%	23.0%	23.0%	22.9%	22.9%	22.7%	22.7%	22.8%	22.8%	23.2%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	3.5%	6.7%	9.9%	13.3%	16.2%	16.2%	16.2%	16.2%	16.2%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
MINIVAN																	
Conventional	100.0%	100.0%	99.9%	99.5%	98.4%	92.8%	87.5%	82.8%	81.3%	80.1%	80.4%	81.5%	81.0%	81.2%	80.1%	80.1%	80.2%
Flex Alcohol	0.0%	0.0%	0.0%	0.0%	0.1%	0.6%	1.2%	1.6%	2.1%	2.4%	2.3%	2.2%	2.1%	1.9%	1.9%	1.8%	1.5%
SDI	0.0%	0.0%	0.0%	0.0%	0.1%	1.5%	2.7%	3.9%	5.0%	6.0%	5.8%	5.4%	5.2%	4.9%	4.8%	4.6%	4.1%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.1%	3.6%	6.8%	9.6%	9.4%	9.2%	9.1%	8.6%	8.7%	8.3%	8.3%	8.1%	7.5%
CNG Dedicated	0.0%	0.0%	0.1%	0.4%	0.7%	0.9%	1.2%	1.4%	1.3%	1.3%	1.2%	1.1%	1.1%	1.0%	1.0%	0.0%	0.0%
Electric	0.0%	0.0%	0.0%	0.0%	0.6%	0.6%	0.7%	0.8%	0.9%	1.0%	1.1%	1.0%	1.0%	0.9%	0.9%	0.8%	0.7%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.9%	1.6%	2.3%	3.1%	3.3%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.8%	1.4%	2.8%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
SUV																	
Conventional	100.0%	100.0%	99.7%	96.7%	95.2%	84.0%	73.2%	61.8%	50.3%	40.7%	40.7%	51.9%	45.5%	48.8%	37.8%	32.0%	26.9%
Flex Alcohol	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SDI	0.0%	0.0%	0.0%	0.0%	1.0%	7.3%	13.0%	18.5%	23.9%	28.7%	28.6%	22.9%	22.5%	18.5%	18.4%	18.3%	18.3%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.1%	2.8%	7.0%	11.7%	16.7%	20.1%	20.1%	16.2%	16.5%	13.7%	13.8%	13.8%	13.9%
CNG Dedicated	0.0%	0.0%	0.3%	3.3%	3.4%	4.5%	4.2%	4.0%	3.9%	3.8%	3.7%	2.9%	2.9%	2.3%	2.3%	2.3%	2.2%
Electric	0.0%	0.0%	0.0%	0.0%	0.2%	1.4%	2.6%	3.9%	5.3%	6.7%	7.0%	5.5%	5.4%	4.4%	4.3%	4.2%	4.0%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	7.3%	11.8%	17.2%	17.5%	17.5%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	6.2%	11.9%	17.1%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PICK-UP AND LARGE VAN																	
Conventional	94.4%	88.6%	86.2%	77.0%	69.7%	66.1%	57.2%	48.8%	43.4%	38.7%	38.8%	38.8%	38.9%	38.9%	38.9%	39.0%	39.1%
Flex Alcohol	5.4%	10.0%	11.1%	14.5%	16.5%	12.4%	12.3%	12.1%	12.0%	12.0%	11.9%	11.8%	11.6%	11.5%	11.4%	11.3%	10.9%
SDI	0.0%	0.0%	0.0%	0.0%	0.1%	6.2%	11.6%	17.1%	22.6%	27.4%	27.4%	27.3%	27.1%	27.0%	26.9%	26.9%	26.9%
Advanced Diesel	0.0%	0.0%	0.7%	5.5%	9.9%	11.1%	14.7%	17.9%	17.9%	17.9%	18.0%	18.1%	18.5%	18.7%	18.9%	18.9%	19.2%
CNG Dedicated	0.2%	1.4%	2.0%	3.0%	3.7%	4.2%	4.2%	4.1%	4.1%	4.1%	4.0%	4.0%	3.9%	3.9%	3.9%	3.9%	3.8%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Ref. VSCC Model

TABLE A-6 Light Duty Vehicle Advanced Technology Market Penetration by Size Class

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
SMALL CAR																	
Conventional	32.5%	32.4%	32.3%	31.6%	26.9%	20.5%	18.0%	13.9%	10.0%	6.7%	6.6%	6.5%	6.5%	6.4%	6.4%	6.4%	6.3%
Flex Alcohol	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SDI	0.0%	0.0%	0.0%	0.0%	0.3%	1.9%	2.7%	3.9%	5.1%	6.0%	5.8%	5.8%	5.7%	5.6%	5.6%	5.5%	5.3%
Advanced Diesel	0.0%	0.0%	0.0%	0.5%	4.7%	9.0%	9.9%	9.8%	9.7%	9.5%	9.5%	9.6%	9.9%	10.0%	10.1%	10.2%	10.7%
CNG Dedicated	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electric	0.0%	0.0%	0.0%	0.1%	0.3%	0.6%	0.8%	1.1%	1.3%	1.4%	1.5%	1.5%	1.4%	1.4%	1.4%	1.4%	1.3%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	2.5%	4.8%	6.8%	6.7%	6.7%	6.6%	6.5%	6.5%	6.5%	6.4%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LARGE CAR																	
Conventional	21.8%	20.4%	18.9%	19.5%	18.7%	16.8%	13.6%	12.1%	9.0%	7.6%	6.8%	6.1%	5.5%	5.6%	5.6%	5.6%	5.6%
Flex Alcohol	2.2%	3.2%	4.1%	3.1%	2.3%	2.0%	1.9%	1.6%	1.5%	1.5%	1.5%	1.5%	1.4%	1.4%	1.4%	1.4%	1.3%
SDI	0.0%	0.0%	0.0%	0.0%	0.2%	1.1%	2.0%	2.4%	3.2%	3.8%	3.7%	3.7%	3.7%	3.7%	3.6%	3.6%	3.6%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	1.0%	1.6%	2.3%	2.3%	2.3%	2.3%	2.4%	2.4%	2.4%	2.4%	2.4%
CNG Dedicated	0.0%	0.3%	0.6%	0.6%	0.6%	0.6%	0.6%	0.5%	0.5%	0.5%	0.5%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hybrid	0.0%	0.0%	0.0%	0.3%	1.5%	2.5%	3.7%	4.2%	5.2%	5.1%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.1%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.8%	1.5%	2.2%	2.9%	3.6%	3.6%	3.6%	3.6%	3.6%
MINIVAN																	
Conventional	11.2%	11.3%	11.3%	11.3%	11.3%	10.7%	10.2%	9.7%	9.6%	9.5%	9.7%	9.8%	9.7%	9.7%	9.6%	9.6%	9.6%
Flex Alcohol	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%
SDI	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%	0.5%	0.6%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%	0.6%	0.5%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.8%	1.1%	1.1%	1.1%	1.1%	1.0%	1.0%	1.0%	1.0%	1.0%	0.9%
CNG Dedicated	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
Electric	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.4%	0.4%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%
SUV																	
Conventional	11.2%	11.3%	11.3%	11.0%	10.9%	9.7%	8.5%	7.2%	5.9%	4.8%	4.9%	6.2%	5.5%	5.9%	4.5%	3.8%	3.2%
Flex Alcohol	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SDI	0.0%	0.0%	0.0%	0.0%	0.1%	0.8%	1.5%	2.2%	2.8%	3.4%	3.4%	2.7%	2.7%	2.2%	2.2%	2.2%	2.2%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.8%	1.4%	2.0%	2.4%	2.4%	1.9%	2.0%	1.6%	1.7%	1.7%	1.7%
CNG Dedicated	0.0%	0.0%	0.0%	0.4%	0.4%	0.5%	0.5%	0.5%	0.5%	0.5%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%	0.5%	0.6%	0.8%	0.8%	0.7%	0.6%	0.5%	0.5%	0.5%	0.5%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.9%	1.4%	2.1%	2.1%	2.1%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.7%	1.4%	2.1%
PICK-UP AND LARGE VAN																	
Conventional	19.8%	18.7%	18.4%	16.6%	15.2%	14.5%	12.8%	11.1%	10.1%	9.1%	9.3%	9.3%	9.3%	9.3%	9.3%	9.4%	9.4%
Flex Alcohol	1.1%	2.1%	2.4%	3.1%	3.6%	2.7%	2.7%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.7%	2.7%	2.6%
SDI	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	2.6%	3.9%	5.2%	6.5%	6.6%	6.6%	6.5%	6.5%	6.5%	6.5%	6.5%
Advanced Diesel	0.0%	0.0%	0.2%	1.2%	2.2%	2.4%	3.3%	4.1%	4.2%	4.2%	4.3%	4.3%	4.4%	4.5%	4.5%	4.5%	4.6%
CNG Dedicated	0.0%	0.3%	0.4%	0.6%	0.8%	0.9%	0.9%	0.9%	0.9%	1.0%	1.0%	1.0%	0.9%	0.9%	0.9%	0.9%	0.9%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Ref. VSCC Model

TABLE A-7 Annual New Light Duty Vehicle Sales
(millions)

Year	Conventional	Advanced Diesel	Alcohol Flex	SDI	CNG	Electric	Hybrid	Fuel Cell	Total
2000	15.31	0.00	0.53	0.00	0.01	0.00	0.00	0.00	15.85
2001	14.69	0.00	0.83	0.00	0.10	0.00	0.00	0.00	15.61
2002	14.40	0.02	1.01	0.00	0.17	0.00	0.00	0.00	15.61
2003	13.98	0.27	0.97	0.00	0.25	0.01	0.04	0.00	15.52
2004	12.99	1.08	0.93	0.09	0.29	0.06	0.23	0.00	15.68
2005	11.40	1.93	0.75	0.85	0.34	0.14	0.39	0.00	15.80
2006	10.07	2.53	0.77	1.46	0.34	0.18	0.63	0.00	15.98
2007	8.60	2.86	0.72	2.05	0.33	0.26	1.07	0.02	15.90
2008	7.06	3.05	0.73	2.68	0.32	0.33	1.58	0.12	15.87
2009	6.00	3.10	0.73	3.23	0.32	0.37	1.88	0.23	15.87
2010	5.94	3.12	0.73	3.23	0.32	0.40	1.87	0.35	15.96
2011	6.08	3.07	0.73	3.10	0.30	0.36	1.89	0.47	15.99
2012	5.85	3.15	0.71	3.07	0.30	0.35	2.01	0.57	16.03
2013	5.98	3.17	0.71	3.00	0.29	0.33	2.13	0.59	16.20
2014	5.77	3.21	0.71	3.00	0.29	0.33	2.26	0.72	16.28
2015	5.69	3.24	0.71	3.01	0.27	0.32	2.29	0.84	16.37
2016	5.80	3.20	0.69	2.97	0.27	0.31	2.27	0.94	16.45
2017	5.83	3.23	0.68	2.98	0.27	0.31	2.28	0.95	16.54
2018	5.86	3.26	0.68	2.98	0.27	0.30	2.30	0.96	16.62
2019	5.89	3.30	0.68	2.99	0.27	0.30	2.31	0.97	16.71
2020	5.73	3.41	0.69	3.04	0.27	0.31	2.35	1.00	16.79

Does not include sales of alternative fuel vehicles estimated in the AEO'98 Reference Case

TABLE A-8 Percent of Total Light Duty Vehicles in Use by Year

Year	Conventional	Advanced Diesel	Alcohol Flex	SDI	CNG	Electric	Hybrid	Fuel Cell	Total Vehicles (million)
2000	99.6%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	205.41
2001	99.2%	0.0%	0.8%	0.0%	0.1%	0.0%	0.0%	0.0%	206.67
2002	98.6%	0.0%	1.3%	0.0%	0.1%	0.0%	0.0%	0.0%	207.25
2003	97.9%	0.1%	1.7%	0.0%	0.3%	0.0%	0.0%	0.0%	207.39
2004	96.6%	0.7%	2.1%	0.0%	0.4%	0.0%	0.1%	0.0%	207.41
2005	94.5%	1.6%	2.5%	0.5%	0.6%	0.1%	0.3%	0.0%	207.32
2006	91.7%	2.8%	2.8%	1.2%	0.7%	0.2%	0.6%	0.0%	207.25
2007	88.3%	4.2%	3.1%	2.2%	0.9%	0.3%	1.1%	0.0%	206.95
2008	84.1%	5.6%	3.3%	3.4%	1.0%	0.5%	1.9%	0.1%	206.52
2009	79.5%	7.1%	3.6%	5.0%	1.2%	0.6%	2.8%	0.2%	205.99
2010	75.0%	8.5%	3.8%	6.6%	1.3%	0.8%	3.7%	0.4%	205.53
2011	70.6%	9.9%	3.9%	8.1%	1.4%	1.0%	4.6%	0.6%	205.09
2012	66.3%	11.2%	4.0%	9.5%	1.5%	1.2%	5.5%	0.9%	204.76
2013	62.2%	12.4%	4.1%	10.8%	1.6%	1.3%	6.4%	1.1%	204.67
2014	58.3%	13.5%	4.2%	12.1%	1.6%	1.4%	7.4%	1.5%	204.75
2015	54.7%	14.5%	4.2%	13.2%	1.6%	1.6%	8.2%	1.9%	205.02
2016	51.5%	15.4%	4.2%	14.2%	1.7%	1.6%	9.0%	2.3%	205.27
2017	48.7%	16.1%	4.2%	15.1%	1.7%	1.7%	9.8%	2.7%	205.59
2018	46.3%	16.8%	4.1%	15.8%	1.7%	1.8%	10.4%	3.1%	205.98
2019	44.3%	17.3%	4.1%	16.4%	1.7%	1.8%	11.0%	3.5%	206.71
2020	42.5%	17.7%	4.0%	16.9%	1.7%	1.9%	11.5%	3.9%	207.33

Does not include sales of alternative fuel vehicles estimated in the AEO'98 Reference Case

TABLE A-9 Number of Light Duty Vehicles in Use by Year
(millions)

Year	Conventional	Advanced Diesel	Alcohol Flex	SDI	CNG	Electric	Hybrid	Fuel Cell	Total
2000	204.63	0.00	0.78	0.00	0.01	0.00	0.00	0.00	205.41
2001	204.96	0.00	1.60	0.00	0.11	0.00	0.00	0.00	206.67
2002	204.35	0.02	2.60	0.00	0.28	0.00	0.00	0.00	207.25
2003	202.96	0.29	3.56	0.00	0.53	0.01	0.04	0.00	207.39
2004	200.34	1.37	4.45	0.09	0.82	0.07	0.27	0.00	207.41
2005	195.92	3.29	5.14	0.94	1.16	0.21	0.67	0.00	207.32
2006	190.07	5.81	5.81	2.41	1.49	0.39	1.29	0.00	207.25
2007	182.67	8.64	6.38	4.45	1.80	0.64	2.36	0.02	206.95
2008	173.76	11.62	6.90	7.12	2.10	0.97	3.92	0.14	206.52
2009	163.85	14.61	7.35	10.33	2.37	1.34	5.77	0.38	205.99
2010	154.10	17.52	7.74	13.52	2.63	1.72	7.58	0.72	205.53
2011	144.78	20.26	8.04	16.54	2.85	2.07	9.37	1.19	205.09
2012	135.71	22.93	8.26	19.44	3.03	2.39	11.23	1.76	204.76
2013	127.33	25.42	8.42	22.17	3.18	2.68	13.13	2.34	204.67
2014	119.43	27.72	8.53	24.72	3.30	2.95	15.05	3.04	204.75
2015	112.19	29.81	8.65	27.07	3.37	3.19	16.89	3.86	205.02
2016	105.78	31.60	8.63	29.14	3.42	3.39	18.56	4.75	205.27
2017	100.15	33.16	8.59	30.96	3.45	3.55	20.09	5.63	205.59
2018	95.33	34.51	8.51	32.55	3.46	3.69	21.46	6.49	205.98
2019	91.54	35.66	8.40	33.88	3.46	3.79	22.68	7.31	206.71
2020	88.12	36.71	8.31	35.01	3.43	3.87	23.77	8.11	207.33

Does not include sales of alternative fuel vehicles estimated in the AEO'98 Reference Case

TABLE A-10 Summation of Gasoline Displaced by Light Duty Vehicles

	Advanced Diesel			**Flex Fuel**				(1) ETOH	**SDI**			(1)	
Year	Gasoline Potential (bill. gals)	Diesel Used (bill. gals)	Gasoline Displaced mmb/d	Gasoline Potential (bill. gals)	ETOH Used (bill. gals)	MEOH Used (bill. gals)	Gasoline Displaced mmb/d	MEOH Used mmb/d	Gasoline Potential (bill. gals)	Gasoline Used (bill. gals)	Electricity Used kWhr	Electricity Used (mmb/d)	Gasoline Displaced mmb/d
2000	0.00	0.00	0.000	0.59	0.00	0.00	0.000	0.000	0.00	0.00	0	0.000	0.000
2001	0.00	0.00	0.000	1.20	0.00	0.00	0.000	0.000	0.00	0.00	0	0.000	0.000
2002	0.02	0.01	0.000	1.90	0.01	0.00	0.000	0.000	0.00	0.00	0	0.000	0.000
2003	0.22	0.14	0.003	2.53	0.02	0.00	0.001	0.001	0.00	0.00	0	0.000	0.000
2004	1.00	0.66	0.014	3.08	0.03	0.00	0.001	0.001	0.07	0.05	0	0.000	0.000
2005	2.38	1.57	0.034	3.46	0.04	0.00	0.002	0.002	0.69	0.55	0	0.000	0.004
2006	4.11	2.71	0.059	3.80	0.07	0.00	0.002	0.002	1.73	1.38	0	0.000	0.010
2007	5.98	3.94	0.086	4.07	0.11	0.00	0.004	0.004	3.14	2.51	0	0.000	0.018
2008	7.85	5.18	0.113	4.28	0.15	0.00	0.005	0.005	4.91	3.92	0	0.000	0.029
2009	9.61	6.33	0.139	4.46	0.21	0.00	0.008	0.008	6.95	5.56	0	0.000	0.041
2010	11.23	7.40	0.162	4.58	0.28	0.00	0.010	0.010	8.86	7.08	0	0.000	0.052
2011	12.65	8.33	0.183	4.66	0.35	0.00	0.013	0.013	10.55	8.44	0	0.000	0.062
2012	13.95	9.20	0.202	4.69	0.43	0.00	0.015	0.015	12.07	9.65	0	0.000	0.071
2013	15.10	9.95	0.218	4.69	0.57	0.00	0.020	0.020	13.40	10.72	0	0.000	0.079
2014	16.09	10.61	0.233	4.67	0.79	0.00	0.028	0.028	14.57	11.65	0	0.000	0.086
2015	16.95	11.17	0.245	4.64	0.91	0.00	0.032	0.032	15.57	12.46	0	0.000	0.092
2016	17.63	11.62	0.255	4.62	0.96	0.00	0.034	0.034	16.40	13.12	0	0.000	0.096
2017	18.19	11.99	0.263	4.52	0.88	0.00	0.032	0.032	17.08	13.67	0	0.000	0.100
2018	18.65	12.29	0.269	4.44	0.89	0.00	0.032	0.032	17.64	14.11	0	0.000	0.104
2019	19.03	12.54	0.275	4.36	0.93	0.00	0.033	0.033	18.07	14.46	0	0.000	0.106
2020	19.39	12.78	0.280	4.30	0.92	0.00	0.033	0.033	18.43	14.74	0	0.000	0.108
Cumulative Total From Year 2000 to Year													
2005	3.6	2.4	0.1	12.8	0.1	0.0	0.0	0.0	0.8	0.6	0.0	0.0	0.0
2010	42.4	27.9	0.6	33.9	0.9	0.0	0.0	0.0	26.3	21.1	0.0	0.0	0.2
2015	117.1	77.2	1.7	57.3	4.0	0.0	0.1	0.1	92.5	74.0	0.0	0.0	0.5
2020	210.0	138.4	3.0	79.5	8.6	0.0	0.3	0.3	180.1	144.1	0.0	0.0	1.1

Gasoline Potential: amount of gasoline used by conventional vehicle, had it not been displaced by new technology.
(1) mmb/d equivalent energy use - conversion of quads to mmb/d.

Year	**Electric** Gasoline Potential (bill. gals)	Electricity Used bill. kWhr	(1) Electricity Used mmb/d	Gasoline Displaced mmb/d	**Fuel Cell** Gasoline Potential (bill. gals)	Gasoline Used (bill. gals)	(1) ETOH Used mmb/d	Gasoline Displaced mmb/d	**Dedicated Alcohol** Gasoline Potential (bill. gals)	ETOH Used (bill. gals)	ETOH Used mmb/d	Gasoline Displaced mmb/d
2000	0.00	0.00	0.000	0.000	0.00	0.00	0.000	0.000	0.00	0.00	0.000	0.000
2001	0.00	0.00	0.000	0.000	0.00	0.00	0.000	0.000	0.00	0.00	0.000	0.000
2002	0.00	0.00	0.000	0.000	0.00	0.00	0.000	0.000	0.00	0.00	0.000	0.000
2003	0.00	0.03	0.000	0.000	0.00	0.00	0.000	0.000	0.00	0.00	0.000	0.000
2004	0.03	0.28	0.002	0.002	0.00	0.00	0.000	0.000	0.00	0.00	0.000	0.000
2005	0.10	0.80	0.004	0.005	0.00	0.00	0.000	0.000	0.00	0.00	0.000	0.000
2006	0.18	1.48	0.008	0.010	0.00	0.00	0.000	0.000	0.00	0.00	0.000	0.000
2007	0.29	2.40	0.013	0.016	0.01	0.01	0.000	0.000	0.00	0.00	0.000	0.000
2008	0.42	3.54	0.020	0.023	0.10	0.05	0.000	0.003	0.00	0.00	0.000	0.000
2009	0.57	4.76	0.026	0.031	0.26	0.12	0.000	0.007	0.00	0.00	0.000	0.000
2010	0.71	5.99	0.033	0.039	0.49	0.23	0.000	0.014	0.00	0.00	0.000	0.000
2011	0.84	7.01	0.039	0.046	0.79	0.38	0.000	0.023	0.00	0.00	0.000	0.000
2012	0.94	7.90	0.044	0.051	1.14	0.54	0.000	0.033	0.00	0.00	0.000	0.000
2013	1.03	8.61	0.048	0.056	1.48	0.71	0.000	0.042	0.00	0.00	0.000	0.000
2014	1.10	9.23	0.051	0.060	1.89	0.90	0.000	0.054	0.00	0.00	0.000	0.000
2015	1.16	9.73	0.054	0.063	2.35	1.12	0.000	0.067	0.00	0.00	0.000	0.000
2016	1.21	10.11	0.056	0.066	2.85	1.36	0.000	0.081	0.00	0.00	0.000	0.000
2017	1.24	10.39	0.058	0.068	3.31	1.58	0.000	0.095	0.00	0.00	0.000	0.000
2018	1.26	10.58	0.059	0.069	3.75	1.79	0.000	0.107	0.00	0.00	0.000	0.000
2019	1.28	10.70	0.059	0.070	4.14	1.98	0.000	0.118	0.00	0.00	0.000	0.000
2020	1.28	10.77	0.060	0.070	4.52	2.16	0.000	0.129	0.00	0.00	0.000	0.000
Cumulative Total From Year 2000 to Year												
2005	0.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	2.3	19.3	0.1	0.1	0.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0
2015	7.4	61.8	0.3	0.4	8.5	4.1	0.0	0.2	0.0	0.0	0.0	0.0
2020	13.6	114.3	0.6	0.7	27.1	12.9	0.0	0.8	0.0	0.0	0.0	0.0

Gasoline Potential: amount of gasoline used by conventional vehicle, had it not been displaced by new technology.
(1) mmb/d equivalent energy use - conversion of quads to mmb/d.

TABLE A-10 Summation of Gasoline Displaced by Light Duty Vehicles

Summary

	Hybrid			**CNG**		(1)	Total	Total	
Year	Gasoline Potential (bill. gals)	Gasoline Used (bill. gals)	Gasoline Displaced mmb/d	Gasoline Potential (bill. gals)	CNG Used mill. cu.ft.	CNG Used mmb/d	Gasoline Displaced mmb/d	Alt. Fuel Used mmb/d	Efficiency mmb/d
1995	0.00	0.00	0.000	0.00	0	0.000	0.000	0.000	0.000
1996	0.00	0.00	0.000	0.00	0	0.000	0.000	0.000	0.000
1997	0.00	0.00	0.000	0.00	0	0.000	0.000	0.000	0.000
1998	0.00	0.00	0.000	0.00	0	0.000	0.000	0.000	0.000
1999	0.00	0.00	0.000	0.00	0	0.000	0.000	0.000	0.000
2000	0.00	0.00	0.000	0.01	1081	0.001	0.001	0.001	0.000
2001	0.00	0.00	0.000	0.08	9206	0.004	0.005	0.005	0.000
2002	0.00	0.00	0.000	0.20	22759	0.011	0.012	0.011	0.000
2003	0.03	0.02	0.001	0.39	42784	0.021	0.025	0.022	0.004
2004	0.20	0.13	0.004	0.58	64697	0.032	0.053	0.034	0.019
2005	0.48	0.29	0.010	0.80	89340	0.044	0.099	0.050	0.050
2006	0.92	0.53	0.021	1.01	112551	0.055	0.157	0.065	0.092
2007	1.65	0.91	0.040	1.20	132742	0.065	0.229	0.082	0.147
2008	2.69	1.43	0.069	1.36	150582	0.073	0.316	0.098	0.217
2009	3.88	2.02	0.101	1.50	166168	0.081	0.408	0.115	0.293
2010	4.97	2.56	0.131	1.62	179544	0.087	0.496	0.131	0.365
2011	5.99	3.06	0.159	1.71	189436	0.092	0.577	0.144	0.433
2012	7.00	3.56	0.187	1.77	196846	0.096	0.655	0.155	0.500
2013	7.99	4.05	0.215	1.82	201709	0.098	0.729	0.166	0.562
2014	8.96	4.53	0.242	1.85	204906	0.100	0.801	0.179	0.622
2015	9.84	4.97	0.266	1.85	205209	0.100	0.865	0.186	0.678
2016	10.60	5.34	0.287	1.84	204494	0.100	0.919	0.190	0.728
2017	11.26	5.67	0.305	1.83	203020	0.099	0.961	0.188	0.772
2018	11.84	5.95	0.321	1.81	201027	0.098	0.999	0.189	0.811
2019	12.32	6.19	0.334	1.79	198498	0.097	1.033	0.189	0.843
2020	12.75	6.40	0.346	1.76	195739	0.095	1.062	0.188	0.874
Cumulative Total From Year 2000 to Year									
2005	0.7	0.4	0.0	2.1	229868	0.1	0.2	0.1	0.1
2010	14.8	7.9	0.4	8.7	971456	0.5	1.8	0.6	1.2
2015	54.6	28.1	1.4	17.7	1969562	1.0	5.4	1.4	4.0
2020	113.4	57.6	3.0	26.8	2972340	1.4	10.4	2.4	8.0

Gasoline Potential: amount of gasoline used by conventional vehicle, had it not been displaced by new technology.
(1) mmb/d equivalent energy use - conversion of quads to mmb/d.

TABLE A-11 Light Truck Class 1&2 Advanced Diesel

	New Sales		Stock		Gasoline	Diesel	Gasoline	Energy Cost	Carbon	Carbon	Criteria Emissions Reductions			Value		
Year	Percent	Units (million)	Percent	Units (million)	Potential (bill. gals)	Used (bill. gals)	Displaced mmb/d	Reduction (billion $)	Reduction (mmt)	Value (mm$)	NOX (MMT)	CO (MMT)	HC (MMT)	NOX (mm$)	CO (mm$)	HC (mm$)
2000	0.0%	0.000	0.0%	0.00	0.00	0.00	0.000	0.000	0.000	0.0	0.000	0.000	0.000	0.0	0.0	0.0
2001	0.0%	0.000	0.0%	0.00	0.00	0.00	0.000	0.000	0.000	0.0	0.000	0.000	0.000	0.0	0.0	0.0
2002	0.2%	0.024	0.0%	0.02	0.02	0.01	0.000	0.009	0.010	0.5	0.000	0.002	0.000	0.0	0.0	0.0
2003	1.2%	0.185	0.0%	0.21	0.16	0.10	0.002	0.074	0.085	4.7	0.000	0.009	0.000	-0.7	3.3	1.8
2004	2.2%	0.342	0.2%	0.55	0.40	0.26	0.006	0.191	0.219	12.1	-0.001	0.024	0.001	-2.1	8.6	4.2
2005	3.2%	0.499	0.6%	1.05	0.75	0.49	0.011	0.364	0.410	22.5	-0.001	0.047	0.002	-4.7	17.0	7.9
2006	4.9%	0.776	1.2%	1.82	1.28	0.84	0.018	0.622	0.701	38.5	-0.003	0.085	0.004	-9.3	30.7	13.8
2007	6.5%	1.035	2.0%	2.84	1.96	1.29	0.028	0.964	1.076	59.2	-0.005	0.139	0.006	-16.4	50.2	21.9
2008	7.2%	1.138	2.9%	3.96	2.67	1.76	0.039	1.314	1.465	80.6	-0.008	0.207	0.009	-26.6	74.7	31.6
2009	7.6%	1.213	3.8%	5.13	3.38	2.23	0.049	1.713	1.853	101.9	-0.012	0.289	0.012	-40.1	104.1	42.9
2010	7.7%	1.234	4.8%	6.29	4.05	2.67	0.058	2.040	2.216	121.9	-0.017	0.382	0.015	-56.9	137.5	55.5
2011	7.4%	1.175	5.6%	7.35	4.61	3.04	0.067	2.345	2.525	138.9	-0.023	0.483	0.019	-76.7	173.8	69.1
2012	7.4%	1.192	6.5%	8.38	5.12	3.37	0.074	2.563	2.805	154.3	-0.030	0.592	0.023	-99.1	213.1	84.2
2013	7.1%	1.149	7.2%	9.29	5.54	3.65	0.080	2.751	3.034	166.9	-0.037	0.703	0.027	-123.0	253.1	99.7
2014	7.1%	1.155	7.9%	10.14	5.90	3.89	0.085	2.969	3.231	177.7	-0.045	0.813	0.032	-147.5	292.8	115.4
2015	7.1%	1.160	8.5%	10.89	6.20	4.09	0.090	3.130	3.397	186.8	-0.052	0.919	0.036	-171.3	330.8	130.7
2016	6.6%	1.089	9.0%	11.48	6.40	4.22	0.092	3.236	3.506	192.8	-0.059	1.013	0.039	-193.3	364.6	144.4
2017	6.6%	1.096	9.5%	11.98	6.55	4.32	0.095	3.319	3.591	197.5	-0.065	1.095	0.043	-212.9	394.2	156.5
2018	6.6%	1.102	9.9%	12.39	6.67	4.40	0.096	3.382	3.654	201.0	-0.070	1.164	0.046	-229.5	419.2	166.9
2019	6.6%	1.108	10.2%	12.72	6.75	4.45	0.098	3.429	3.699	203.4	-0.074	1.220	0.048	-243.2	439.3	175.3
2020	7.1%	1.188	10.5%	13.05	6.86	4.52	0.099	3.486	3.756	206.6	-0.077	1.268	0.050	-254.2	456.4	182.8
Cumulative Total From Year 2000 to Year																
2005					1.32	0.87	0.02	0.64	0.72	39.83	0.00	0.08	0.00	-7.46	28.97	13.97
2010					14.67	9.67	0.21	7.29	8.04	441.95	-0.05	1.19	0.05	-156.68	426.11	179.69
2015					42.03	27.70	0.61	21.05	23.03	1266.50	-0.23	4.70	0.19	-774.18	1689.69	678.78
2020					75.26	49.60	1.09	37.90	41.23	2267.84	-0.58	10.46	0.41	-1907.19	3763.43	1504.64

Carbon value/tonne = $55
NOx value/tonne = $3,300
CO value/tonne = $360
HC value/tonne = 3,660

TABLE A-12 Projected Biofuels Demand

Year	FFV Percent ETOH	FFV ETOH (mill. gals)	DED ETOH (mill. gals)	FCV ETOH (mill. gals)	Total Direct Fuel Use Biomass ETOH (million gals)	Total Direct Fuel Use Biomass ETOH (mmb/de)	Blends and Extenders (million gals)	Blends and Extenders (mmb/de)	Program Goals (million gals)
2000	0.1%	1.31	0.00	0.00	1.3	0.000	0.0	0.000	1.3
2001	0.2%	3.69	0.00	0.00	3.7	0.000	6.0	0.000	9.7
2002	0.3%	7.86	0.00	0.00	7.9	0.000	26.0	0.001	33.9
2003	0.4%	15.32	0.00	0.00	15.3	0.001	50.0	0.002	65.3
2004	0.6%	26.42	0.00	0.00	26.4	0.001	100.0	0.004	126.4
2005	0.9%	44.92	0.00	0.00	44.9	0.002	600.0	0.024	644.9
2006	1.1%	66.00	0.00	0.00	66.0	0.002	1200.0	0.048	1266.0
2007	1.8%	107.87	0.00	0.00	107.9	0.004	1800.0	0.072	1907.9
2008	2.3%	149.73	0.00	0.00	149.7	0.005	2400.0	0.096	2549.7
2009	3.1%	211.66	0.00	0.00	211.7	0.008	3000.0	0.120	3211.7
2010	4.1%	282.21	0.00	0.00	282.2	0.010	4000.0	0.160	4282.2
2011	5.0%	353.80	0.00	0.00	353.8	0.013	5000.0	0.200	5353.8
2012	6.0%	428.88	0.00	0.00	428.9	0.015	6000.0	0.240	6428.9
2013	8.0%	566.77	0.00	0.00	566.8	0.020	7000.0	0.280	7566.8
2014	11.0%	785.57	0.00	0.00	785.6	0.028	8000.0	0.320	8785.6
2015	12.9%	906.31	0.00	0.00	906.3	0.032	8500.0	0.340	9406.3
2016	13.8%	964.82	0.00	0.00	964.8	0.034	9000.0	0.360	9964.8
2017	12.9%	884.24	0.00	0.00	884.2	0.032	9500.0	0.380	10384.2
2018	13.3%	893.72	0.00	0.00	893.7	0.032	10000.0	0.400	10893.7
2019	14.1%	930.02	0.00	0.00	930.0	0.033	10500.0	0.420	11430.0
2020	14.2%	924.65	0.00	0.00	924.6	0.033	11000.0	0.440	11924.6
Cumulative Total From Year 2000 to Year									
2005		99.5	0.00	0.00	99.5	0.00	782	0.03	882
2010		917.0	0.00	0.00	917.0	0.03	13182	0.53	14099
2015		3958.3	0.00	0.00	3958.3	0.14	47682	1.91	51640
2020		8555.8	0.00	0.00	8555.8	0.31	97682	3.90	106238

Dedicated Alcohol Vehicle assumes E-85 fuel mix, this is taken into account in the calculation of total ethanol used.
The percent of total fuel consumed that is ethanol by flex fuel vehicles is shown in column 2.

TABLE A-13 EPACT Light Duty Fleet Alternative Fuel Use Estimates

	Quads					**Carbon Reduction - Million Metric Tons**					**Energy Cost Savings - Billion 1996 $**				
Year	Total CNG	Total LPG	Total ETOH	Total MEOH	TOTAL	CNG	LPG	ETOH	MEOH	TOTAL	CNG	LPG	ETOH	MEOH	TOTAL
2000	0.043	0.021	0.0000	0.000	0.064	0.213	0.047	0.000	0.001	0.261	0.183	-0.061	0.000	0.000	0.121
2001	0.064	0.028	0.0001	0.000	0.093	0.317	0.063	0.001	0.002	0.383	0.275	-0.083	0.000	-0.001	0.191
2002	0.085	0.036	0.0001	0.001	0.121	0.418	0.080	0.002	0.004	0.505	0.363	-0.111	0.000	-0.001	0.251
2003	0.102	0.045	0.0001	0.001	0.149	0.505	0.102	0.003	0.005	0.615	0.440	-0.140	0.000	-0.002	0.297
2004	0.116	0.056	0.0002	0.001	0.174	0.575	0.127	0.003	0.006	0.711	0.495	-0.175	0.000	-0.002	0.317
2005	0.127	0.068	0.0002	0.001	0.196	0.626	0.152	0.004	0.007	0.788	0.534	-0.210	0.000	-0.003	0.322
2006	0.132	0.076	0.0002	0.002	0.209	0.651	0.171	0.004	0.008	0.833	0.532	-0.234	0.000	-0.003	0.295
2007	0.134	0.082	0.0002	0.002	0.217	0.660	0.184	0.004	0.008	0.857	0.529	-0.247	0.000	-0.003	0.279
2008	0.136	0.085	0.0002	0.002	0.222	0.670	0.191	0.005	0.009	0.874	0.513	-0.259	0.000	-0.003	0.250
2009	0.138	0.086	0.0003	0.002	0.226	0.681	0.194	0.005	0.010	0.889	0.502	-0.263	0.000	-0.004	0.235
2010	0.140	0.087	0.0003	0.002	0.230	0.691	0.197	0.005	0.010	0.903	0.483	-0.266	0.000	-0.005	0.212
2011	0.141	0.088	0.0003	0.002	0.232	0.698	0.198	0.005	0.011	0.912	0.465	-0.259	0.000	-0.006	0.200
2012	0.142	0.089	0.0003	0.002	0.234	0.704	0.199	0.006	0.011	0.920	0.452	-0.269	0.000	-0.008	0.174
2013	0.144	0.089	0.0003	0.002	0.235	0.709	0.201	0.006	0.012	0.928	0.452	-0.259	0.000	-0.008	0.185
2014	0.144	0.090	0.0003	0.002	0.237	0.713	0.201	0.006	0.012	0.933	0.459	-0.252	0.000	-0.008	0.200
2015	0.145	0.090	0.0003	0.003	0.237	0.715	0.202	0.006	0.013	0.936	0.445	-0.257	0.000	-0.007	0.181
2016	0.145	0.090	0.0003	0.003	0.238	0.716	0.202	0.007	0.013	0.938	0.436	-0.263	0.000	-0.010	0.164
2017	0.145	0.090	0.0004	0.003	0.238	0.718	0.202	0.007	0.013	0.940	0.417	-0.254	0.000	-0.009	0.154
2018	0.146	0.090	0.0004	0.003	0.239	0.720	0.202	0.007	0.014	0.943	0.411	-0.260	0.000	-0.013	0.139
2019	0.146	0.090	0.0004	0.003	0.239	0.721	0.203	0.007	0.014	0.945	0.413	-0.252	0.000	-0.013	0.149
2020	0.146	0.090	0.0004	0.003	0.240	0.723	0.203	0.007	0.014	0.947	0.404	-0.251	0.000	-0.012	0.141
Cumulative Total From Year 2000 to Year															
2005	0.537	0.254	0.001	0.005	0.797	2.654	0.571	0.013	0.025	3.262	2.290	-0.781	-0.0013	-0.009	1.499
2010	1.216	0.669	0.002	0.014	1.902	6.008	1.506	0.035	0.070	7.619	4.849	-2.049	-0.0020	-0.028	2.770
2015	1.741	1.030	0.003	0.025	2.799	8.599	2.318	0.062	0.122	11.101	6.300	-3.090	-0.0006	-0.062	3.147
2020	2.661	1.565	0.005	0.040	4.271	13.145	3.520	0.100	0.197	16.962	9.203	-4.626	0.0008	-0.121	4.456

TABLE A-14 ZEV and EPACT Light Duty Electric Vehicle Fuel Use Estimates

	Trillion Btu			**Quads**			**Carbon Reduction Million Metric Tons**			**Energy Cost Savings Billion 1996 $**		
Year	EPACT	ZEV	Total	EPACT	ZEV	Total	EPACT	ZEV	Total	EPACT	ZEV	Total
2000	0.85	2.44	3.29	0.0009	0.0024	0.0033	0.0000	0.0000	0.0000	4.16	11.94	16.10
2001	1.20	4.36	5.56	0.0012	0.0044	0.0056	0.0001	0.0003	0.0004	6.01	21.84	27.86
2002	1.54	6.31	7.85	0.0015	0.0063	0.0079	0.0002	0.0008	0.0010	7.83	32.08	39.90
2003	1.81	19.86	21.67	0.0018	0.0199	0.0217	0.0003	0.0038	0.0041	9.45	103.74	113.19
2004	1.99	32.35	34.34	0.0020	0.0324	0.0343	0.0005	0.0081	0.0086	10.62	172.64	183.26
2005	2.05	43.66	45.71	0.0021	0.0437	0.0457	0.0006	0.0135	0.0142	11.22	238.97	250.19
2006	2.01	53.92	55.93	0.0020	0.0539	0.0559	0.0010	0.0264	0.0274	11.12	298.18	309.29
2007	1.88	62.63	64.51	0.0019	0.0626	0.0645	0.0013	0.0420	0.0432	10.67	355.32	365.99
2008	1.75	71.08	72.83	0.0018	0.0711	0.0728	0.0015	0.0604	0.0619	9.95	404.21	414.16
2009	1.64	79.68	81.32	0.0016	0.0797	0.0813	0.0017	0.0821	0.0838	9.39	456.04	465.42
2010	1.56	87.62	89.18	0.0016	0.0876	0.0892	0.0019	0.1060	0.1079	8.93	501.48	510.41
2011	1.52	94.98	96.50	0.0015	0.0950	0.0965	0.0022	0.1377	0.1399	8.81	550.57	559.38
2012	1.51	100.99	102.50	0.0015	0.1010	0.1025	0.0026	0.1707	0.1732	8.81	589.11	597.92
2013	1.52	106.48	108.00	0.0015	0.1065	0.1080	0.0029	0.2055	0.2084	9.02	631.78	640.80
2014	1.52	111.88	113.40	0.0015	0.1119	0.1134	0.0033	0.2428	0.2461	9.22	678.37	687.58
2015	1.53	117.17	118.70	0.0015	0.1172	0.1187	0.0037	0.2824	0.2861	9.29	711.22	720.51
2016	1.53	122.37	123.90	0.0015	0.1224	0.1239	0.0039	0.3096	0.3135	9.34	746.86	756.20
2017	1.53	127.57	129.10	0.0015	0.1276	0.1291	0.0041	0.3381	0.3421	9.22	768.40	777.61
2018	1.53	132.47	134.00	0.0015	0.1325	0.1340	0.0042	0.3669	0.3712	9.26	801.44	810.70
2019	1.53	137.17	138.70	0.0015	0.1372	0.1387	0.0044	0.3964	0.4008	9.38	841.31	850.69
2020	1.53	141.77	143.30	0.0015	0.1418	0.1433	0.0046	0.4267	0.4313	9.38	869.05	878.43
Cumulative Total From Year 2000 to Year												
2005	9.44	108.98	118.42	0.01	0.11	0.12	0.00	0.03	0.03	49.29	581.2	630.5
2010	18.28	463.91	482.19	0.02	0.46	0.48	0.01	0.34	0.35	99.34	2596.4	2695.8
2015	25.88	995.41	1021.29	0.03	1.00	1.02	0.02	1.38	1.41	144.48	5757.5	5901.9
2020	33.53	1656.76	1690.29	0.03	1.66	1.69	0.04	3.22	3.27	191.06	9784.5	9975.6

TABLE A-15 Light Duty Vehicle Energy Cost Savings

Year	Advanced Diesel	Flex Fuel	SDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.004
2001	0.000	-0.001	0.000	0.000	0.000	0.000	0.041	0.040
2002	0.005	-0.001	0.000	0.000	0.000	0.000	0.101	0.105
2003	0.066	-0.002	0.000	0.003	0.000	0.011	0.190	0.267
2004	0.305	-0.004	0.008	0.025	0.000	0.085	0.284	0.704
2005	0.732	-0.005	0.086	0.073	0.000	0.221	0.389	1.496
2006	1.265	-0.006	0.217	0.136	0.000	0.447	0.469	2.527
2007	1.862	-0.007	0.397	0.225	0.007	0.862	0.542	3.890
2008	2.443	-0.007	0.621	0.333	0.062	1.480	0.587	5.518
2009	2.996	-0.005	0.881	0.450	0.161	2.186	0.624	7.292
2010	3.492	-0.001	1.120	0.566	0.303	2.829	0.639	8.947
2011	3.934	0.003	1.334	0.667	0.487	3.433	0.643	10.501
2012	4.332	0.010	1.524	0.754	0.702	4.027	0.643	11.992
2013	4.719	0.024	1.703	0.833	0.917	4.647	0.655	13.499
2014	5.090	0.052	1.874	0.909	1.181	5.288	0.672	15.064
2015	5.340	0.070	1.995	0.958	1.463	5.796	0.650	16.271
2016	5.553	0.076	2.101	0.998	1.771	6.251	0.635	17.384
2017	5.669	0.063	2.166	1.013	2.039	6.577	0.601	18.127
2018	5.812	0.065	2.236	1.035	2.306	6.919	0.585	18.957
2019	5.965	0.073	2.305	1.058	2.565	7.250	0.579	19.795
2020	6.072	0.073	2.348	1.064	2.797	7.500	0.557	20.412
Cumulative Total From Year 2000 to Year								
2005	1.11	-0.01	0.09	0.10	0.00	0.32	1.01	2.62
2010	13.17	-0.04	3.33	1.81	0.53	8.12	3.87	30.79
2015	36.58	0.12	11.76	5.93	5.28	31.31	7.13	98.12
2020	65.65	0.47	22.92	11.10	16.76	65.81	10.09	192.79

Billions of 1996 $'s
See Transportation Energy Prices for Fuel Prices

TABLE A-16 Transportation Energy Prices

	1996 Dollars per Million Btu						1996 Dollars per 125,000 Btu					
Year	Gasoline	Diesel	LPG	CNG	Electricity	Ethanol	Gasoline	Diesel	LPG	CNG	Electricity	Ethanol
1995	9.23	8.03	12.62	5.77	15.14	18.96	1.15	1.11	1.58	0.72	1.89	2.37
1996	9.89	8.90	12.62	5.41	15.33	17.73	1.24	1.23	1.58	0.68	1.92	2.22
1997	9.59	8.37	12.64	6.17	15.40	16.50	1.20	1.16	1.58	0.77	1.93	2.06
1998	9.37	8.18	12.61	5.69	15.08	15.26	1.17	1.13	1.58	0.71	1.89	1.91
1999	9.56	8.46	12.73	5.56	14.91	14.03	1.20	1.17	1.59	0.70	1.86	1.75
2000	9.78	8.51	12.72	5.53	14.66	12.80	1.22	1.18	1.59	0.69	1.83	1.60
2001	9.82	8.55	12.80	5.54	14.43	12.54	1.23	1.19	1.60	0.69	1.80	1.57
2002	9.82	8.58	12.92	5.53	14.21	12.29	1.23	1.19	1.62	0.69	1.78	1.54
2003	9.90	8.61	12.99	5.60	14.03	12.03	1.24	1.19	1.62	0.70	1.75	1.50
2004	9.95	8.66	13.06	5.70	13.84	11.78	1.24	1.20	1.63	0.71	1.73	1.47
2005	10.06	8.70	13.17	5.84	13.76	11.52	1.26	1.21	1.65	0.73	1.72	1.44
2006	10.06	8.66	13.14	6.02	13.59	11.26	1.26	1.20	1.64	0.75	1.70	1.41
2007	10.18	8.73	13.21	6.22	13.52	11.01	1.27	1.21	1.65	0.78	1.69	1.38
2008	10.17	8.68	13.23	6.39	13.45	10.75	1.27	1.20	1.65	0.80	1.68	1.34
2009	10.19	8.72	13.24	6.55	13.40	10.50	1.27	1.21	1.66	0.82	1.68	1.31
2010	10.17	8.59	13.21	6.72	13.34	10.24	1.27	1.19	1.65	0.84	1.67	1.28
2011	10.17	8.59	13.11	6.88	13.12	10.05	1.27	1.19	1.64	0.86	1.64	1.26
2012	10.15	8.51	13.19	6.98	12.95	9.86	1.27	1.18	1.65	0.87	1.62	1.23
2013	10.22	8.60	13.13	7.07	12.86	9.66	1.28	1.19	1.64	0.88	1.61	1.21
2014	10.34	8.60	13.15	7.16	12.83	9.47	1.29	1.19	1.64	0.90	1.60	1.18
2015	10.30	8.57	13.16	7.23	12.69	9.28	1.29	1.19	1.65	0.90	1.59	1.16
2016	10.30	8.52	13.23	7.29	12.59	9.26	1.29	1.18	1.65	0.91	1.57	1.16
2017	10.19	8.46	13.02	7.32	12.50	9.25	1.27	1.17	1.63	0.92	1.56	1.16
2018	10.19	8.50	13.08	7.37	12.42	9.23	1.27	1.18	1.64	0.92	1.55	1.15
2019	10.25	8.51	13.05	7.42	12.35	9.22	1.28	1.18	1.63	0.93	1.54	1.15
2020	10.24	8.48	13.02	7.48	12.33	9.20	1.28	1.18	1.63	0.94	1.54	1.15
2021	10.18	8.39	12.88	7.73	11.97	9.12	1.27	1.16	1.61	0.97	1.50	1.15
2022	10.12	8.30	12.74	7.98	11.61	9.04	1.27	1.15	1.59	1.00	1.45	1.15
2023	10.06	8.21	12.60	8.23	11.25	8.96	1.26	1.14	1.58	1.03	1.41	1.15
2024	10.00	8.12	12.46	8.48	10.89	8.88	1.25	1.13	1.56	1.06	1.36	1.15
2025	9.94	8.03	12.32	8.73	10.53	8.80	1.24	1.11	1.54	1.09	1.32	1.15

DOE/EIA-0383(98), Annual Energy Outlook 1998, Reference Case Forecast Table A3. Energy Prices by Sector and Source
Prices Include Federal and State taxes and exclude county and local taxes.
Ethanol: Programs goals as stated in FY 2000 Budget.

TABLE A-17 Total Carbon Emission Reductions

Million Metric Tons per Year

Year	Advanced Diesel	Flex Fuel	SDI	Electric	Fuel Cell	Hybrid	CNG	EPAct LDV Fleets	ZEV Mandates	Heavy Duty	Blends	Total Reduction	Total Carbon Emissions
2000	0.000	0.002	0.000	0.000	0.000	0.000	0.006	0.261	0.000	0.175	0.000	0.444	491.8
2001	0.000	0.005	0.000	0.000	0.000	0.000	0.047	0.383	0.000	0.303	0.010	0.748	499.0
2002	0.000	0.011	0.000	0.000	0.000	0.000	0.116	0.505	0.001	0.443	0.041	1.117	505.2
2003	0.034	0.022	0.000	0.001	0.000	0.022	0.218	0.615	0.004	0.661	0.080	1.656	511.6
2004	0.330	0.038	0.016	0.012	0.000	0.166	0.330	0.711	0.009	0.944	0.159	2.715	518.4
2005	0.893	0.064	0.167	0.034	0.000	0.426	0.455	0.788	0.014	1.293	0.956	5.089	526.0
2006	1.551	0.094	0.418	0.066	0.000	0.862	0.573	0.833	0.027	1.734	1.912	8.070	532.5
2007	2.201	0.154	0.757	0.111	0.014	1.644	0.676	0.857	0.043	2.262	2.867	11.587	538.4
2008	2.837	0.213	1.185	0.172	0.116	2.824	0.767	0.874	0.062	2.807	3.823	15.681	543.8
2009	3.413	0.302	1.678	0.242	0.301	4.164	0.846	0.889	0.084	3.351	4.779	20.049	548.1
2010	3.934	0.402	2.138	0.317	0.567	5.398	0.915	0.903	0.108	3.869	6.372	24.923	552.4
2011	4.403	0.504	2.546	0.390	0.913	6.553	0.965	0.912	0.140	4.329	7.965	29.621	552.4
2012	4.840	0.611	2.914	0.462	1.318	7.701	1.003	0.920	0.173	4.764	9.558	34.264	552.4
2013	5.236	0.808	3.235	0.528	1.711	8.826	1.027	0.928	0.208	5.153	11.151	38.812	552.4
2014	5.586	1.119	3.517	0.592	2.176	9.927	1.044	0.933	0.246	5.519	12.743	43.403	552.4
2015	5.889	1.291	3.760	0.652	2.708	10.922	1.045	0.936	0.286	5.867	13.540	46.896	571.7
2016	6.150	1.375	3.960	0.692	3.278	11.779	1.042	0.938	0.313	6.180	14.336	50.042	575.6
2017	6.373	1.260	4.125	0.725	3.814	12.528	1.034	0.940	0.342	6.490	15.133	52.764	579.4
2018	6.562	1.273	4.259	0.754	4.314	13.179	1.024	0.943	0.371	6.801	15.929	55.410	583.3
2019	6.724	1.325	4.364	0.777	4.771	13.729	1.011	0.945	0.401	7.120	16.726	57.894	587.1
2020	6.866	1.317	4.450	0.798	5.207	14.217	0.997	0.947	0.431	7.480	17.522	60.232	591.0
Cumulative Total From Year 2000 to Year													
2005	1.26	0.14	0.18	0.05	0.00	0.61	1.17	3.26	0.03	3.82	1.25	11.77	
2010	15.19	1.31	6.36	0.95	1.00	15.51	4.95	7.62	0.35	17.84	21.00	92.08	
2015	41.15	5.64	22.33	3.58	9.82	59.44	10.03	12.25	1.41	43.48	75.95	285.07	
2020	73.82	12.19	43.49	7.33	31.21	124.87	15.14	16.96	3.27	77.55	155.60	561.42	

Carbon Coefficients: DOE/EIA-0573, Emissions of Greenhouse Gases In the United States, Table 6. pg. 15.

Gasoline = 19.41 CNG = 14.47 = 4.94 Ethanol = 0.5823

Diesel = 19.95 LPG = 17.16 = 2.25 Electric Utilities = 22.32 (NREL, QM)

Ethanol Reduction = 97% of Gasoline Carbon Coefficient: 19.41 x 0.97 = 18.8277

Total Carbon Emissions: Annual Energy Outlook 1996, DOE/EIA-0383(96), Table A19 Carbon Emissions by End-Use Sector and Source, pg. 118.

TABLE A-18 Value of Carbon Emission Reductions

(million 1996 $)

Year	Advanced Diesel	Flex Fuel	SDI	Electric	Fuel Cell	Hybrid	CNG	EPAct LDV Fleets	ZEV Mandates	Heavy Duty	Blends	Total Reduction
2000	0.0	0.1	0.0	0.0	0.0	0.0	0.3	14.3	0.0	9.6	0.0	24.4
2001	0.0	0.3	0.0	0.0	0.0	0.0	2.6	21.1	0.0	16.7	0.5	41.2
2002	0.0	0.6	0.0	0.0	0.0	0.0	6.4	27.8	0.1	24.4	2.3	61.5
2003	1.9	1.2	0.0	0.1	0.0	1.2	12.0	33.8	0.2	36.3	4.4	91.1
2004	18.2	2.1	0.9	0.6	0.0	9.1	18.1	39.1	0.5	51.9	8.8	149.3
2005	49.1	3.5	9.2	1.9	0.0	23.4	25.0	43.3	0.8	71.1	52.6	279.9
2006	85.3	5.2	23.0	3.6	0.0	47.4	31.5	45.8	1.5	95.4	105.1	443.8
2007	121.0	8.5	41.7	6.1	0.7	90.4	37.2	47.1	2.4	124.4	157.7	637.3
2008	156.0	11.7	65.1	9.5	6.4	155.3	42.2	48.1	3.4	154.4	210.3	862.4
2009	187.7	16.6	92.3	13.3	16.6	229.0	46.6	48.9	4.6	184.3	262.8	1102.7
2010	216.4	22.1	117.6	17.4	31.2	296.9	50.3	49.7	5.9	212.8	350.4	1370.8
2011	242.2	27.7	140.1	21.5	50.2	360.4	53.1	50.2	7.7	238.1	438.1	1629.1
2012	266.2	33.6	160.3	25.4	72.5	423.6	55.1	50.6	9.5	262.0	525.7	1884.5
2013	288.0	44.4	177.9	29.1	94.1	485.4	56.5	51.0	11.5	283.4	613.3	2134.6
2014	307.2	61.6	193.4	32.6	119.7	546.0	57.4	51.3	13.5	303.5	700.9	2387.2
2015	323.9	71.0	206.8	35.9	148.9	600.7	57.5	51.5	15.7	322.7	744.7	2579.3
2016	338.3	75.6	217.8	38.0	180.3	647.8	57.3	51.6	17.2	339.9	788.5	2752.3
2017	350.5	69.3	226.9	39.9	209.8	689.0	56.9	51.7	18.8	356.9	832.3	2902.0
2018	360.9	70.0	234.3	41.5	237.3	724.9	56.3	51.9	20.4	374.1	876.1	3047.6
2019	369.8	72.9	240.0	42.7	262.4	755.1	55.6	52.0	22.0	391.6	919.9	3184.1
2020	377.6	72.5	244.8	43.9	286.4	781.9	54.8	52.1	23.7	411.4	963.7	3312.8
Cumulative Total From Year 2000 to Year												
2005	69.1	7.8	10.1	2.6	0.0	33.8	64.4	179.4	1.6	210.1	68.5	647.3
2010	835.6	71.9	349.8	52.5	54.9	852.9	272.1	419.0	19.4	981.4	1154.9	5064.3
2015	2263.1	310.2	1228.3	196.9	540.3	3268.9	551.8	673.7	77.3	2391.2	4177.5	15679.1
2020	4060.2	670.5	2392.0	402.9	1716.4	6867.7	832.7	932.9	179.6	4265.1	8558.1	30877.9

$55/ton

TABLE A-19 NOx Emission Reductions

Million Metric Tons per Year

Year	Advanced Diesel	Flex Fuel	SDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0001
2003	-0.0003	0.0000	0.0000	0.0000	0.0000	0.0003	-0.0001	0.0000
2004	-0.0013	0.0022	0.0001	0.0003	0.0000	0.0005	-0.0001	0.0015
2005	-0.0038	0.0045	0.0006	0.0007	0.0000	0.0011	-0.0002	0.0030
2006	-0.0082	0.0075	0.0016	0.0014	0.0000	0.0021	-0.0002	0.0043
2007	-0.0147	0.0111	0.0029	0.0024	0.0000	0.0039	-0.0002	0.0054
2008	-0.0236	0.0146	0.0046	0.0038	0.0002	0.0064	-0.0002	0.0058
2009	-0.0353	0.0194	0.0066	0.0054	0.0007	0.0092	-0.0001	0.0059
2010	-0.0498	0.0247	0.0085	0.0072	0.0015	0.0119	-0.0001	0.0040
2011	-0.0668	0.0303	0.0102	0.0091	0.0027	0.0145	0.0000	-0.0001
2012	-0.0857	0.0357	0.0117	0.0111	0.0043	0.0171	0.0000	-0.0057
2013	-0.1054	0.0409	0.0131	0.0132	0.0063	0.0196	0.0001	-0.0122
2014	-0.1252	0.0475	0.0144	0.0152	0.0089	0.0222	0.0001	-0.0169
2015	-0.1442	0.0539	0.0154	0.0172	0.0122	0.0245	0.0001	-0.0208
2016	-0.1617	0.0529	0.0163	0.0190	0.0162	0.0266	0.0002	-0.0306
2017	-0.1773	0.0555	0.0171	0.0206	0.0206	0.0284	0.0002	-0.0350
2018	-0.1909	0.0575	0.0177	0.0219	0.0254	0.0299	0.0002	-0.0382
2019	-0.2025	0.0590	0.0182	0.0230	0.0305	0.0313	0.0002	-0.0403
2020	-0.2123	0.0601	0.0187	0.0238	0.0357	0.0325	0.0002	-0.0413
Cumulative Total From Year 2000 to Year								
2005	-0.0055	0.0067	0.0007	0.0010	0.0000	0.0019	-0.0004	0.0045
2010	-0.1371	0.0840	0.0250	0.0213	0.0025	0.0354	-0.0012	0.0299
2015	-0.6644	0.2923	0.0899	0.0871	0.0368	0.1333	-0.0009	-0.0259
2020	-1.6092	0.5774	0.1780	0.1954	0.1652	0.2820	0.0000	-0.2112

TABLE A-20 Value of NOx Emission Reductions

(million 1996 $)

Year	Advanced Diesel	Flex Fuel	SDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
2002	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	-0.3
2003	-0.9	0.0	0.0	0.1	0.0	1.0	-0.3	0.0
2004	-4.4	7.3	0.2	0.9	0.0	1.5	-0.4	5.1
2005	-12.5	14.9	2.1	2.4	0.0	3.7	-0.6	10.0
2006	-26.9	24.7	5.3	4.7	0.0	7.0	-0.7	14.2
2007	-48.5	36.5	9.7	8.0	0.1	12.7	-0.6	17.9
2008	-77.9	48.2	15.3	12.4	0.8	21.0	-0.5	19.2
2009	-116.5	64.0	21.8	17.8	2.3	30.5	-0.4	19.5
2010	-164.5	81.6	28.1	23.9	4.9	39.4	-0.3	13.1
2011	-220.6	99.9	33.6	30.2	8.8	47.8	-0.1	-0.4
2012	-282.7	117.9	38.8	36.8	14.1	56.3	0.1	-18.8
2013	-347.9	135.0	43.3	43.4	20.7	64.8	0.2	-40.4
2014	-413.1	156.7	47.4	50.1	29.4	73.2	0.4	-55.9
2015	-475.9	178.0	51.0	56.7	40.3	80.9	0.5	-68.6
2016	-533.6	174.6	53.9	62.6	53.3	87.7	0.5	-100.9
2017	-585.2	183.2	56.5	67.9	68.0	93.6	0.6	-115.5
2018	-630.1	189.9	58.5	72.3	83.9	98.8	0.6	-126.1
2019	-668.3	194.8	60.2	75.9	100.6	103.3	0.6	-133.0
2020	-700.6	198.3	61.6	78.6	118.0	107.2	0.6	-136.2
Cumulative Total From Year 2000 to Year								
2005	-18.0	22.2	2.3	3.4	0.0	6.2	-1.5	14.8
2010	-452.3	277.2	82.5	70.2	8.1	116.8	-4.0	98.7
2015	-2192.4	964.7	296.6	287.4	121.3	439.9	-2.9	-85.4
2020	-5310.3	1905.5	587.3	644.7	545.1	930.5	0.0	-697.0

$3,300/ton

TABLE A-21 CO Emission Reductions

Million Metric Tons per Year

Year	Advanced Diesel	Flex Fuel	SDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0005
2001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0044	0.0044
2002	0.0021	0.0001	0.0000	0.0000	0.0000	0.0000	0.0118	0.0140
2003	0.0123	0.0003	0.0000	0.0005	0.0000	0.0003	0.0244	0.0378
2004	0.0547	0.0461	0.0000	0.0026	0.0000	0.0005	0.0350	0.1388
2005	0.1374	0.0929	0.0001	0.0074	0.0000	0.0011	0.0482	0.2872
2006	0.2592	0.1519	0.0004	0.0148	0.0000	0.0021	0.0634	0.4918
2007	0.4160	0.2205	0.0007	0.0259	0.0006	0.0039	0.0805	0.7479
2008	0.6052	0.2890	0.0010	0.0412	0.0055	0.0064	0.0996	1.0479
2009	0.8272	0.3790	0.0015	0.0607	0.0157	0.0092	0.1183	1.4116
2010	1.0818	0.4775	0.0019	0.0844	0.0325	0.0119	0.1360	1.8260
2011	1.3608	0.5791	0.0023	0.1102	0.0572	0.0145	0.1518	2.2760
2012	1.6589	0.6782	0.0026	0.1384	0.0904	0.0171	0.1653	2.7510
2013	1.9616	0.7724	0.0029	0.1680	0.1307	0.0196	0.1763	3.2316
2014	2.2578	1.0244	0.0032	0.1984	0.1827	0.0222	0.1850	3.8737
2015	2.5372	1.1283	0.0035	0.2283	0.2470	0.0245	0.1909	4.3597
2016	2.7897	0.9876	0.0037	0.2561	0.3233	0.0266	0.1947	4.5816
2017	3.0141	1.0308	0.0038	0.2809	0.4077	0.0284	0.1967	4.9624
2018	3.2087	1.0654	0.0040	0.3019	0.4975	0.0299	0.1971	5.3045
2019	3.3740	1.0915	0.0041	0.3190	0.5910	0.0313	0.1948	5.6058
2020	3.5164	1.1090	0.0042	0.3324	0.6874	0.0325	0.1910	5.8729
Cumulative Total From Year 2000 to Year								
2005	0.21	0.14	0.00	0.01	0.00	0.00	0.12	0.48
2010	3.40	1.66	0.01	0.24	0.05	0.04	0.62	6.01
2015	13.17	5.84	0.02	1.08	0.76	0.13	1.49	22.50
2020	29.08	11.12	0.04	2.57	3.27	0.28	2.47	48.83

TABLE A-22 Value of CO Emission Reductions

(million 1996 $)

Year	Advanced Diesel	Flex Fuel	SDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2
2001	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.6
2002	0.7	0.0	0.0	0.0	0.0	0.0	4.3	5.0
2003	4.4	0.1	0.0	0.2	0.0	0.1	8.8	13.6
2004	19.7	16.6	0.0	0.9	0.0	0.2	12.6	50.0
2005	49.5	33.5	0.1	2.7	0.0	0.4	17.4	103.4
2006	93.3	54.7	0.1	5.3	0.0	0.8	22.8	177.0
2007	149.8	79.4	0.2	9.3	0.2	1.4	29.0	269.3
2008	217.9	104.1	0.4	14.8	2.0	2.3	35.9	377.3
2009	297.8	136.4	0.5	21.9	5.6	3.3	42.6	508.2
2010	389.4	171.9	0.7	30.4	11.7	4.3	49.0	657.4
2011	489.9	208.5	0.8	39.7	20.6	5.2	54.7	819.3
2012	597.2	244.2	0.9	49.8	32.6	6.1	59.5	990.4
2013	706.2	278.1	1.1	60.5	47.0	7.1	63.5	1163.4
2014	812.8	368.8	1.2	71.4	65.8	8.0	66.6	1394.5
2015	913.4	406.2	1.2	82.2	88.9	8.8	68.7	1569.5
2016	1004.3	355.5	1.3	92.2	116.4	9.6	70.1	1649.4
2017	1085.1	371.1	1.4	101.1	146.8	10.2	70.8	1786.5
2018	1155.1	383.5	1.4	108.7	179.1	10.8	70.9	1909.6
2019	1214.7	392.9	1.5	114.8	212.8	11.3	70.1	2018.1
2020	1265.9	399.2	1.5	119.7	247.5	11.7	68.8	2114.2
Cumulative Total From Year 2000 to Year								
2005	74.3	50.2	0.1	3.8	0.0	0.7	44.7	173.8
2010	1222.5	596.7	2.0	85.5	19.5	12.7	223.9	2162.9
2015	4742.0	2102.3	7.3	389.1	274.4	48.0	536.9	8100.0
2020	10467.0	4004.7	14.4	925.6	1176.9	101.5	887.7	17577.8

$360/ton

TABLE A-23 HC Emission Reductions

Million Metric Tons per Year

Year	Advanced Diesel	Flex Fuel	SDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0008
2001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0073	0.0073
2002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0188	0.0189
2003	0.0006	0.0000	0.0000	0.0000	0.0000	0.0003	0.0368	0.0379
2004	0.0027	0.0018	0.0000	0.0003	0.0000	0.0001	0.0531	0.0581
2005	0.0065	0.0036	0.0002	0.0009	0.0000	0.0004	0.0721	0.0837
2006	0.0116	0.0060	0.0005	0.0017	0.0000	0.0007	0.0929	0.1134
2007	0.0178	0.0089	0.0009	0.0029	0.0001	0.0012	0.1157	0.1475
2008	0.0248	0.0119	0.0015	0.0044	0.0006	0.0020	0.1418	0.1870
2009	0.0329	0.0166	0.0021	0.0063	0.0017	0.0029	0.1667	0.2292
2010	0.0423	0.0220	0.0027	0.0086	0.0033	0.0038	0.1903	0.2730
2011	0.0527	0.0279	0.0032	0.0110	0.0056	0.0046	0.2109	0.3160
2012	0.0641	0.0338	0.0037	0.0136	0.0086	0.0054	0.2283	0.3576
2013	0.0759	0.0399	0.0042	0.0164	0.0119	0.0063	0.2424	0.3970
2014	0.0876	0.0871	0.0046	0.0194	0.0164	0.0071	0.2538	0.4760
2015	0.0987	0.0938	0.0049	0.0224	0.0221	0.0078	0.2613	0.5110
2016	0.1088	0.0545	0.0052	0.0252	0.0289	0.0085	0.2661	0.4972
2017	0.1179	0.0567	0.0054	0.0279	0.0363	0.0090	0.2689	0.5222
2018	0.1258	0.0589	0.0056	0.0301	0.0443	0.0095	0.2699	0.5441
2019	0.1326	0.0606	0.0058	0.0320	0.0526	0.0100	0.2674	0.5609
2020	0.1385	0.0616	0.0059	0.0335	0.0613	0.0103	0.2625	0.5737
Cumulative Total From Year 2000 to Year								
2005	0.010	0.005	0.000	0.001	0.000	0.001	0.189	0.207
2010	0.139	0.071	0.008	0.025	0.006	0.012	0.896	1.157
2015	0.518	0.354	0.029	0.108	0.070	0.043	2.093	3.214
2020	1.142	0.646	0.057	0.256	0.294	0.090	3.428	5.913

TABLE A-24 Value of HC Emission Reductions

(million 1996 $)

Year	Advanced Diesel	Flex Fuel	SDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.1
2001	0.0	0.0	0.0	0.0	0.0	0.0	26.7	26.8
2002	0.5	0.1	0.0	0.0	0.0	0.0	68.8	69.3
2003	2.4	0.2	0.0	0.2	0.0	1.2	134.9	138.7
2004	9.9	6.6	0.1	1.1	0.0	0.5	194.4	212.5
2005	23.6	13.3	0.7	3.3	0.0	1.3	264.0	306.2
2006	42.4	21.9	1.9	6.3	0.0	2.5	339.9	414.9
2007	65.0	32.7	3.4	10.5	0.3	4.5	423.5	539.9
2008	90.8	43.5	5.4	16.2	2.3	7.4	518.8	684.4
2009	120.5	60.7	7.7	23.1	6.2	10.8	610.0	839.0
2010	154.8	80.7	9.9	31.4	12.2	13.9	696.4	999.3
2011	193.0	102.2	11.9	40.1	20.6	16.9	771.8	1156.4
2012	234.8	123.8	13.7	49.7	31.3	19.9	835.6	1308.8
2013	277.9	146.0	15.3	60.0	43.7	22.9	887.2	1452.9
2014	320.6	318.9	16.7	70.9	60.1	25.9	929.0	1742.2
2015	361.4	343.4	18.0	81.9	80.8	28.6	956.2	1870.3
2016	398.4	199.4	19.0	92.4	105.6	31.0	973.9	1819.7
2017	431.5	207.7	19.9	101.9	133.0	33.1	984.3	1911.4
2018	460.4	215.5	20.7	110.2	162.0	34.9	987.8	1991.5
2019	485.1	221.9	21.3	117.0	192.3	36.5	978.7	2052.8
2020	506.9	225.5	21.8	122.5	224.2	37.9	960.9	2099.7
Cumulative Total From Year 2000 to Year								
2005	36.3	20.1	0.8	4.6	0.0	3.0	691.8	756.7
2010	509.8	259.6	29.1	92.0	21.0	42.1	3280.6	4234.2
2015	1897.5	1293.9	104.7	394.6	257.5	156.2	7660.4	11764.8
2020	4179.9	2363.9	207.4	938.6	1074.7	329.5	12545.9	21639.8

$3,660/ton

TABLE A-25 Light Vehicle Purchase Price

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
Conventional	19.09	19.39	19.70	20.01	20.34	20.67	21.01	21.36	21.73	22.10	22.48	22.86	23.25	23.65	24.05	24.47	26.47
OTT Programs	19.27	19.68	20.08	20.49	20.89	21.28	21.69	21.90	22.34	22.76	23.16	23.56	23.97	24.36	24.84	25.29	27.33
SMALL CAR Purchase Price																	
Conventional	15.49	15.64	15.80	15.96	16.12	16.28	16.44	16.60	16.77	16.94	17.11	17.28	17.45	17.62	17.80	17.98	18.90
Advanced Diesel	N/A	N/A	N/A	17.07	17.25	17.42	17.59	17.77	17.94	18.11	18.28	18.45	18.62	18.79	18.97	19.15	20.07
Flex Alcohol	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDI	N/A	N/A	N/A	N/A	16.92	17.03	17.13	17.24	17.34	17.45	17.62	17.79	17.96	18.13	18.31	18.49	19.41
CNG Dedicated	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Electric	N/A	N/A	N/A	23.93	23.32	22.72	22.11	21.50	20.89	20.28	19.67	19.84	20.01	20.18	20.36	20.54	21.46
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	18.08	18.26	18.45	18.63	18.82	19.01	19.20	19.39	19.58	19.78	20.79
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AVERAGE	15.49	15.64	15.80	15.99	16.36	16.77	17.01	17.35	17.67	17.94	18.08	18.26	18.44	18.62	18.80	18.98	19.92
LARGE CAR Purchase Price																	
Conventional	23.93	24.34	24.75	25.17	25.61	26.05	26.50	26.96	27.43	27.91	28.40	28.89	29.40	29.92	30.45	30.99	33.58
Advanced Diesel	N/A	N/A	N/A	N/A	N/A	27.87	28.26	28.65	29.04	29.43	29.81	30.31	30.82	31.34	31.87	32.41	35.00
Flex Alcohol	23.93	24.34	24.75	25.17	25.61	26.05	26.50	26.96	27.43	27.91	28.40	28.89	29.40	29.92	30.45	30.99	33.58
SDI	N/A	N/A	N/A	N/A	26.89	27.26	27.65	28.07	28.50	28.75	29.24	29.73	30.24	30.76	31.29	31.83	34.42
CNG Dedicated	26.44	26.54	26.65	26.75	26.86	26.96	27.41	27.87	28.34	28.82	29.31	29.80	30.31	30.83	31.36	31.90	34.49
Electric	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hybrid	N/A	N/A	N/A	28.95	28.92	28.89	28.86	28.83	28.80	29.28	29.77	30.26	30.77	31.29	31.82	32.36	34.95
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32.35	32.34	32.34	32.34	32.34	32.34	32.86	33.39	33.93	36.52
AVERAGE	23.93	24.36	24.79	25.25	25.86	26.44	27.09	27.59	28.25	28.84	29.41	29.97	30.50	31.02	31.54	32.09	34.68
MINIVAN MARKET SHARES																	
Conventional	23.93	24.34	24.75	25.17	25.61	26.05	26.50	26.96	27.43	27.91	28.40	28.89	29.40	29.92	30.45	30.99	33.58
Advanced Diesel	N/A	N/A	N/A	N/A	27.53	27.99	28.46	28.93	29.40	29.86	30.35	30.84	31.35	31.87	32.40	32.94	35.53
Flex Alcohol	23.93	24.34	24.75	25.17	25.61	26.05	26.50	26.96	27.43	27.91	28.40	28.89	29.40	29.92	30.45	30.99	33.58
SDI	N/A	N/A	N/A	N/A	26.89	27.26	27.63	28.00	28.37	28.75	29.24	29.73	30.24	30.76	31.29	31.83	34.42
CNG Dedicated	N/A	N/A	25.98	26.41	26.85	27.29	27.74	28.20	28.67	29.15	29.64	30.13	30.64	31.16	31.69	32.23	34.82
Electric	N/A	N/A	N/A	N/A	38.41	37.92	37.44	36.95	36.47	35.98	35.49	35.99	36.50	37.02	37.55	38.09	40.68
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32.36	32.79	33.22	33.65	34.08	36.68
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	34.41	34.94	35.48	38.07
AVERAGE	23.93	24.34	24.75	25.18	25.70	26.22	26.75	27.28	27.75	28.24	28.72	29.20	29.73	30.26	30.83	31.40	34.03
SUV																	
Conventional	22.64	23.09	23.54	24.02	24.50	24.99	25.49	25.99	26.52	27.05	27.59	28.14	28.70	29.28	29.86	30.46	33.33
Advanced Diesel	N/A	N/A	N/A	N/A	26.34	26.86	27.38	27.90	28.42	28.95	29.48	30.03	30.59	31.17	31.75	32.35	35.22
Flex Alcohol	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDI	N/A	N/A	N/A	N/A	25.72	26.15	26.58	27.01	27.44	27.86	28.40	28.95	29.51	30.09	30.67	31.27	34.14
CNG Dedicated	N/A	N/A	24.72	25.20	25.68	26.17	26.67	27.17	27.70	28.23	28.77	29.32	29.88	30.46	31.04	31.64	34.51
Electric	N/A	N/A	N/A	N/A	36.75	36.37	35.99	35.62	35.24	34.86	34.49	35.04	35.60	36.18	36.76	37.36	40.23
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	31.52	32.01	32.50	33.00	33.51	36.37
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	33.67	34.25	34.85	37.72
AVERAGE	22.64	23.09	23.55	24.05	24.58	25.34	26.09	26.83	27.56	28.23	28.73	29.07	29.84	30.42	31.41	32.24	35.33
PICK-UP AND LARGE VAN																	
Conventional	15.31	15.62	15.93	16.24	16.57	16.90	17.24	17.58	17.93	18.30	18.66	19.03	19.42	19.81	20.20	20.60	22.55
Advanced Diesel	N/A	N/A	17.52	17.78	18.04	18.30	18.55	18.81	19.16	19.53	19.89	20.26	20.65	21.04	21.43	21.83	23.78
Flex Alcohol	15.31	15.62	15.93	16.24	16.57	16.90	17.24	17.58	17.93	18.30	18.66	19.03	19.42	19.81	20.20	20.60	22.55
SDI	N/A	N/A	N/A	N/A	17.40	17.69	17.98	18.27	18.56	18.85	19.21	19.58	19.97	20.36	20.75	21.15	23.10
CNG Dedicated	16.99	17.30	17.61	17.92	18.25	17.75	18.09	18.43	18.78	19.15	19.51	19.88	20.27	20.66	21.05	21.45	23.40
Electric	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AVERAGE	15.31	15.64	15.97	16.38	16.78	17.14	17.56	17.95	18.33	18.70	19.07	19.44	19.83	20.22	20.61	21.02	22.96

TABLE A-26 Total Consumer Investment - billion 1996$

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
SMALL CAR																	
Conventional	79.793	79.115	79.627	78.317	67.865	52.709	47.291	36.739	26.485	18.019	17.927	18.053	18.067	18.335	18.518	18.771	19.997
Advanced Diesel	0.000	0.000	0.000	1.394	12.641	24.651	27.812	27.667	27.536	27.428	27.569	28.187	29.417	30.495	31.327	32.117	36.016
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SDI	0.000	0.000	0.000	0.000	0.671	5.162	7.489	10.740	13.905	16.510	16.338	16.373	16.288	16.460	16.560	16.685	17.366
CNG Dedicated	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Electric	0.000	0.000	0.000	0.190	1.136	2.240	2.669	3.605	4.460	4.592	4.741	4.705	4.617	4.624	4.615	4.583	4.509
Hybrid	0.000	0.000	0.000	0.000	0.000	0.000	0.608	7.320	13.968	19.994	20.007	20.276	20.263	20.567	20.795	21.042	22.433
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	79.793	79.115	79.627	79.901	82.313	84.762	85.868	86.071	86.353	86.543	86.582	87.594	88.652	90.480	91.815	93.198	100.321
LARGE CAR																	
Conventional	82.864	77.434	73.147	76.122	74.945	68.984	57.428	51.950	39.010	33.539	30.961	28.353	26.151	26.942	27.563	28.224	31.361
Advanced Diesel	0.000	0.000	0.000	0.000	0.000	0.377	4.619	7.485	10.708	10.744	10.890	11.133	11.612	12.071	12.421	12.731	14.221
Flex Alcohol	8.396	12.101	15.918	12.245	9.301	8.099	8.113	6.782	6.693	6.661	6.670	6.706	6.713	6.826	6.907	7.011	7.420
SDI	0.000	0.000	0.000	0.000	0.693	4.669	8.811	10.887	14.261	17.256	17.406	17.639	17.794	18.234	18.587	18.992	20.972
CNG Dedicated	0.168	1.295	2.474	2.370	2.423	2.600	2.593	2.167	2.130	2.114	2.108	2.115	2.116	2.157	2.190	2.221	2.381
Electric	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hybrid	0.000	0.000	0.000	1.128	6.772	11.358	17.112	19.363	23.569	23.696	23.951	24.347	24.633	25.340	25.947	26.583	29.888
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.527	4.033	7.598	11.279	15.148	18.524	18.990	19.380	19.784	21.871
TOTAL	91.428	90.830	91.540	91.864	94.134	96.086	98.676	99.161	100.403	101.607	103.265	105.440	107.543	110.560	112.995	115.546	128.113
MINIVAN																	
Conventional	42.568	42.845	43.736	44.296	45.195	43.901	42.985	41.509	41.737	42.233	43.750	45.182	45.810	47.215	47.662	48.772	54.230
Advanced Diesel	0.000	0.000	0.000	0.000	0.027	1.824	3.565	5.141	5.168	5.200	5.277	5.109	5.250	5.173	5.232	5.250	5.373
Flex Alcohol	0.009	0.008	0.008	0.008	0.045	0.304	0.571	0.825	1.075	1.282	1.276	1.208	1.183	1.133	1.119	1.106	1.028
SDI	0.000	0.000	0.000	0.000	0.070	0.726	1.380	2.024	2.672	3.239	3.244	3.090	3.047	2.937	2.918	2.897	2.810
CNG Dedicated	0.000	0.000	0.027	0.205	0.346	0.454	0.598	0.713	0.702	0.695	0.690	0.652	0.639	0.615	0.612	0.018	0.017
Electric	0.000	0.000	0.000	0.000	0.425	0.430	0.486	0.544	0.605	0.677	0.760	0.712	0.690	0.656	0.643	0.627	0.567
Hybrid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.071	0.555	1.028	1.534	2.054	2.402
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.068	0.515	0.952	2.143
TOTAL	42.577	42.854	43.771	44.509	46.107	47.640	49.586	50.755	51.959	53.326	54.996	56.024	57.176	58.827	60.236	61.676	68.571
SUV																	
Conventional	40.282	40.661	41.532	41.050	41.847	38.135	34.575	29.911	24.958	20.813	21.492	28.036	25.093	27.777	22.056	19.169	18.071
Advanced Diesel	0.000	0.000	0.000	0.000	0.068	1.358	3.543	6.093	8.901	10.969	11.326	9.321	9.700	8.312	8.546	8.745	9.883
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SDI	0.000	0.000	0.000	0.000	0.479	3.483	6.418	9.295	12.254	15.120	15.542	12.696	12.786	10.814	11.009	11.249	12.576
CNG Dedicated	0.000	0.000	0.120	1.478	1.581	2.136	2.073	2.026	1.997	2.019	2.044	1.647	1.641	1.380	1.400	1.417	1.534
Electric	0.000	0.000	0.000	0.000	0.124	0.924	1.742	2.591	3.487	4.399	4.615	3.717	3.684	3.077	3.097	3.111	3.268
Hybrid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.360	4.496	7.446	11.091	11.506	12.854
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.339	4.171	8.139	13.006
TOTAL	40.282	40.661	41.652	42.527	44.099	46.037	48.351	49.916	51.598	53.320	55.018	55.776	57.402	59.144	61.369	63.337	71.193
PICK-UP AND LARGE VAN																	
Conventional	48.026	45.702	45.770	41.912	39.468	38.844	35.306	31.084	28.621	26.531	27.716	28.359	29.044	29.973	30.741	31.561	35.563
Advanced Diesel	0.000	0.000	0.420	3.301	6.126	7.063	9.780	12.189	12.623	13.090	13.688	14.073	14.720	15.330	15.807	16.241	18.407
Flex Alcohol	2.731	5.150	5.875	7.865	9.330	7.261	7.561	7.739	7.951	8.193	8.485	8.597	8.650	8.828	8.975	9.148	9.901
SDI	0.000	0.000	0.000	0.000	0.083	3.823	7.495	11.329	15.449	19.329	20.142	20.535	20.787	21.345	21.823	22.360	25.074
CNG Dedicated	0.106	0.820	1.196	1.785	2.316	2.589	2.690	2.757	2.827	2.911	3.008	3.044	3.064	3.136	3.200	3.262	3.594
Electric	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hybrid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	50.863	51.672	53.261	54.864	57.323	59.579	62.832	65.097	67.471	70.052	73.039	74.609	76.265	78.612	80.547	82.571	92.538
TOTAL INVESTMENT	304.942	305.132	309.852	313.664	323.976	334.104	345.313	351.000	357.785	364.849	372.900	379.443	387.037	397.622	406.961	416.327	460.737

Total Consumer Investment - billion $

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
Advanced Auto	4.727	8.139	12.152	16.064	18.668	21.451	27.239	23.877	47.199	70.768	96.467	103.758	112.290	120.503	134.524	143.813	164.183
Materials	4.727	8.139	12.152	16.064	18.668	21.451	27.239	21.968	25.693	31.892	41.342	47.983	55.480	61.742	74.139	82.289	96.420
Tech Util	5.824	8.775	12.506	17.095	21.530	24.616	26.664	26.988	28.314	28.524	29.450	29.237	29.913	28.351	28.369	28.594	30.132
Biofuels	16.905	26.843	37.208	43.646	47.301	43.180	43.862	39.911	40.430	38.581	39.395	40.398	41.667	42.008	42.703	43.706	49.274
Heavy Duty	0.157	0.441	0.902	2.856	12.805	22.437	32.599	43.903	53.760	55.055	56.837	56.114	57.846	55.883	57.971	59.630	67.254
Total	15853787	15611598	15605203	15521876	15677932	15797644	15977657	15901829	15865459	15870487	15960229	15991185	16028013	16201181	16281923	16369182	16791278

TABLE A-27 Total Incremental Consumer Investment - billion 1996$

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
SMALL CAR																	
Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Advanced Diesel	0.000	0.000	0.000	0.091	0.829	1.620	1.827	1.815	1.801	1.772	1.765	1.788	1.848	1.898	1.932	1.962	2.100
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dedicated Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG Dedicated	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SDI	0.000	0.000	0.000	0.000	0.032	0.227	0.302	0.394	0.458	0.481	0.473	0.469	0.463	0.463	0.461	0.460	0.456
CNG Dedicated	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CNG Bi-fuel	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Electric	0.000	0.000	0.000	0.063	0.351	0.635	0.684	0.821	0.880	0.757	0.618	0.607	0.591	0.586	0.580	0.571	0.538
Hybrid	0.000	0.000	0.000	0.000	0.000	0.000	0.055	0.665	1.270	1.818	1.819	1.843	1.842	1.870	1.890	1.913	2.039
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	0.000	0.000	0.000	0.154	1.212	2.482	2.869	3.695	4.409	4.828	4.675	4.708	4.744	4.817	4.864	4.907	5.134
LARGE CAR																	
Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Advanced Diesel	0.000	0.000	0.000	0.000	0.000	0.025	0.288	0.443	0.595	0.554	0.519	0.522	0.535	0.547	0.554	0.558	0.577
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dedicated Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG Dedicated	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SDI	0.000	0.000	0.000	0.000	0.033	0.207	0.367	0.432	0.539	0.503	0.500	0.498	0.494	0.498	0.499	0.501	0.512
CNG Dedicated	0.016	0.108	0.177	0.140	0.113	0.088	0.086	0.071	0.068	0.067	0.065	0.065	0.064	0.064	0.064	0.063	0.063
CNG Bi-fuel	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Electric	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hybrid	0.000	0.000	0.000	0.147	0.775	1.115	1.397	1.257	1.122	1.109	1.102	1.102	1.097	1.110	1.117	1.126	1.172
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.088	0.613	1.042	1.377	1.617	1.684	1.699	1.707	1.715	1.761
TOTAL	0.016	0.108	0.177	0.287	0.921	1.434	2.138	2.290	2.938	3.273	3.563	3.803	3.874	3.917	3.940	3.963	4.084
MINIVAN																	
Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Advanced Diesel	0.000	0.000	0.000	0.000	0.002	0.127	0.246	0.351	0.346	0.340	0.339	0.323	0.327	0.317	0.315	0.311	0.295
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dedicated Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG Dedicated	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SDI	0.000	0.000	0.000	0.000	0.003	0.032	0.056	0.076	0.089	0.094	0.093	0.087	0.085	0.080	0.078	0.076	0.069
CNG Dedicated	0.000	0.000	0.001	0.010	0.016	0.021	0.027	0.031	0.030	0.030	0.029	0.027	0.026	0.024	0.024	0.001	0.001
CNG Bi-fuel	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Electric	0.000	0.000	0.000	0.000	0.142	0.135	0.142	0.147	0.150	0.152	0.152	0.141	0.134	0.126	0.122	0.117	0.099
Hybrid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.057	0.102	0.146	0.187	0.203
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.066	0.120	0.253
TOTAL	0.000	0.000	0.001	0.010	0.163	0.314	0.471	0.605	0.616	0.616	0.613	0.585	0.629	0.658	0.751	0.812	0.919
SUV																	
Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Advanced Diesel	0.000	0.000	0.000	0.000	0.005	0.094	0.245	0.417	0.598	0.718	0.726	0.587	0.599	0.504	0.509	0.511	0.530
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dedicated Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG Dedicated	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SDI	0.000	0.000	0.000	0.000	0.023	0.155	0.263	0.349	0.411	0.440	0.443	0.355	0.351	0.291	0.291	0.291	0.298
CNG Dedicated	0.000	0.000	0.006	0.069	0.073	0.096	0.092	0.088	0.085	0.084	0.084	0.066	0.065	0.053	0.053	0.053	0.052
CNG Bi-fuel	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Electric	0.000	0.000	0.000	0.000	0.041	0.289	0.508	0.700	0.863	0.986	0.923	0.732	0.714	0.587	0.581	0.575	0.561
Hybrid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.039	0.464	0.738	1.054	1.046	1.074
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.044	0.535	1.025	1.514
TOTAL	0.000	0.000	0.006	0.069	0.141	0.634	1.108	1.553	1.958	2.228	2.176	1.779	2.193	2.217	3.022	3.501	4.030
PICK-UP AND LARGE VAN																	
Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Advanced Diesel	0.000	0.000	0.038	0.285	0.498	0.537	0.692	0.797	0.810	0.824	0.846	0.854	0.877	0.896	0.907	0.915	0.952
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dedicated Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG Dedicated	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SDI	0.000	0.000	0.000	0.000	0.004	0.170	0.307	0.425	0.519	0.563	0.577	0.577	0.573	0.577	0.578	0.581	0.597
CNG Dedicated	0.010	0.080	0.114	0.167	0.213	0.123	0.126	0.127	0.128	0.129	0.131	0.130	0.128	0.129	0.129	0.129	0.131
CNG Bi-fuel	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Electric	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hybrid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	0.010	0.080	0.152	0.452	0.715	0.830	1.126	1.350	1.457	1.517	1.554	1.561	1.578	1.602	1.615	1.625	1.680
Technology Utilization	0.026	0.187	0.298	0.386	0.415	0.328	0.331	0.317	0.312	0.310	0.309	0.288	0.283	0.271	0.270	0.246	0.246
Fuels Development	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Advanced Auto Tech	0.000	0.000	0.000	0.317	2.246	4.621	6.209	7.584	9.223	10.155	10.246	10.212	10.761	11.034	11.945	12.524	13.465
Advanced Materials	0.000	0.000	0.000	0.010	0.069	0.125	0.159	0.210	0.295	0.353	0.368	0.375	0.391	0.396	0.460	0.515	0.582
Heavy Vehicle Tech	0.000	0.000	0.038	0.260	0.424	0.620	1.013	1.382	1.548	1.645	1.659	1.562	1.582	1.511	1.517	1.523	1.553
TOTAL INC. INVEST.	0.026	0.187	0.336	0.972	3.153	5.695	7.712	9.493	11.378	12.462	12.582	12.436	13.017	13.212	14.193	14.808	15.847

TABLE A-28 Incremental Capital Expenditures for Advanced Vehicle Production

Million 1996$

Year	Advanced Diesel	CNG	Electric	Hybrid	Fuel Cell	Total
2000	0	9	0	0	0	$9
2001	0	59	0	0	0	$59
2002	7	49	0	0	0	$57
2003	73	62	16	78	0	$228
2004	243	26	110	390	0	$769
2005	256	34	144	318	0	$753
2006	179	1	93	467	0	$740
2007	101	0	146	892	33	$1,171
2008	57	0	148	1006	217	$1,428
2009	16	0	85	614	220	$934
2010	5	0	50	0	228	$282
2011	0	0	0	34	239	$274
2012	10	0	0	257	209	$476
2013	3	0	0	234	34	$272
2014	13	0	0	257	254	$524
2015	10	0	0	60	253	$323
2016	0	0	0	0	197	$197
2017	0	0	0	0	20	$20
2018	6	0	0	16	20	$43
2019	10	0	0	24	10	$44
2020	33	0	0	88	66	$187
Cumulative Total From Year 2000 to Year						
2005	579	238	271	786	0	1875
2010	936	240	792	3765	697	6431
2015	973	240	792	4608	1687	8300
2020	1022	240	792	4736	2000	8790

Advanced Diesel: $300 million/100,000 vehicles
CNG: $700 million/100,000 vehicles
Electric, Hybrid, Fuel Cell: $2 billion/100,000 vehicles

Capital Expenditures for Advanced Vehicle Production

Million 1994$

Year	Advanced Diesel	CNG	Electric	Hybrid	Fuel Cell	Total		billion	
	0.0000	0.0126	0.0000	0.0000	0.0000		2000	31.71	$32
	0.0000	0.0836	0.0000	0.0000	0.0000		2001	31.22	$31
	0.0240	0.0705	0.0000	0.0000	0.0000		2002	31.21	$31
	0.2434	0.0879	0.0079	0.0390	0.0000		2003	31.04	$31
	0.8088	0.0370	0.0552	0.1952	0.0000		2004	31.36	$32
	0.8542	0.0490	0.0722	0.1590	0.0000		2005	31.60	$32
	0.5956	0.0020	0.0467	0.2334	0.0000		2006	31.96	$33
	0.3363	0.0000	0.0731	0.4459	0.0163		2007	31.80	$33
	0.1887	0.0000	0.0739	0.5032	0.1084		2008	31.73	$33
	0.0522	0.0000	0.0424	0.3068	0.1102		2009	31.74	$33
	0.0167	0.0000	0.0248	0.0000	0.1138		2010	31.92	$32
	0.0000	0.0000	0.0000	0.0171	0.1196		2011	31.98	$32
	0.0342	0.0000	0.0000	0.1285	0.1044		2012	32.06	$33
	0.0112	0.0000	0.0000	0.1171	0.0172		2013	32.40	$33
	0.0440	0.0000	0.0000	0.1285	0.1271		2014	32.56	$33
	0.0342	0.0000	0.0000	0.0300	0.1265		2015	32.74	$33
	0.0000	0.0000	0.0000	0.0000	0.0986		2016	32.91	$33
	0.0000	0.0000	0.0000	0.0000	0.0099		2017	33.07	$33
	0.0203	0.0000	0.0000	0.0082	0.0102		2018	33.25	$33
	0.0348	0.0000	0.0000	0.0118	0.0050		2019	33.41	$33
	0.1086	0.0000	0.0000	0.0442	0.0328		2020	33.58	$34

Capital Expenditure Calculation

Year	New Car Sales	Percent Trans./ Import	Sales Trans./ Imports	Car Sales Domestic	New Lt. Trk Sales	Percent Trans./ Import	Sales Trans./ Imports	Lt Trk Sales Domestic	(1000) Total Domestic LDV Sales	Capital Exp. (billions)	$/veh.
1991	6137	13.7%	841	5296	4123	17.3%	713	3410	8706	15.6	1792
1992	6277	14.1%	885	5392	4629	14.1%	653	3976	9368	14.6	1558
1993	6742	14.9%	1005	5737	5351	13.9%	744	4607	10345	16.1	1556
1994	7255	16.5%	1197	6058	6033	14.6%	881	5152	11210	18.5	1650
1995	7129	18.9%	1347	5782	6053	14.0%	847	5206	10987	21.5	1957
1996	7254	20.2%	1465	5789	6519	14.1%	919	5600	11389	22.7	1993
1997	6917	21.5%	1487	5430	6600	14.1%	931	5669	11099	23.0	2072

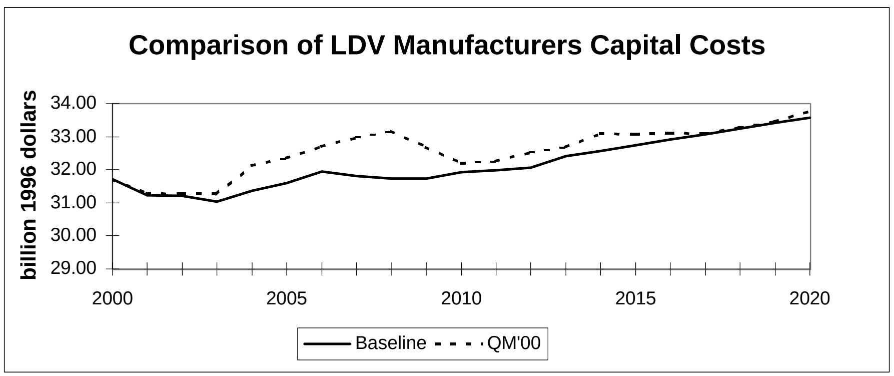


TABLE A-29 New Light Vehicle Fuel Economy

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
Conventional	24.56	24.76	24.96	25.15	25.35	25.55	25.80	26.05	26.30	26.55	26.80	27.06	27.31	27.57	27.82	28.08	28.08
OTT Programs	24.56	24.76	24.97	25.31	26.00	26.92	27.95	29.18	30.65	31.73	32.20	32.51	33.09	33.40	34.06	34.61	34.80
SMALL CAR FUEL ECONOMY																	
Conventional	31.26	31.64	32.01	32.39	32.76	33.14	33.57	34.00	34.43	34.86	35.29	35.57	35.85	36.14	36.42	36.70	36.70
Advanced Diesel	N/A	N/A	N/A	43.72	44.23	44.74	45.32	45.90	46.48	47.06	47.64	48.02	48.40	48.78	49.16	49.55	49.55
Flex Alcohol	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDI	N/A	N/A	N/A	N/A	40.96	41.43	41.96	42.50	43.04	43.58	44.11	44.47	44.82	45.17	45.52	45.88	45.88
CNG Dedicated	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Electric	N/A	N/A	N/A	129.55	131.06	132.56	134.28	136.00	137.72	139.44	141.16	142.29	143.42	144.54	145.67	146.80	146.80
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	55.39	58.48	61.63	64.84	68.11	71.14	71.71	72.27	72.84	73.40	73.40
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AVERAGE	31.26	31.64	32.01	32.56	34.37	36.79	38.11	40.75	43.88	47.02	48.02	48.68	49.03	49.39	49.76	50.12	50.02
LARGE CAR FUEL ECONOMY																	
Conventional	25.86	26.12	26.38	26.63	26.89	27.15	27.48	27.80	28.13	28.45	28.78	28.92	29.07	29.21	29.36	29.50	29.50
Advanced Diesel	N/A	N/A	N/A	N/A	N/A	36.65	37.09	37.53	37.97	38.41	38.85	39.05	39.24	39.44	39.63	39.83	39.83
Flex Alcohol	25.86	26.12	26.38	26.63	26.89	27.15	27.48	27.80	28.13	28.45	28.78	28.92	29.07	29.21	29.36	29.50	29.50
SDI	N/A	N/A	N/A	N/A	33.62	33.94	34.35	34.75	35.16	35.57	35.98	36.16	36.34	36.52	36.70	36.88	36.88
CNG Dedicated	25.86	26.12	26.38	26.63	26.89	27.15	27.48	27.80	28.13	28.45	28.78	28.92	29.07	29.21	29.36	29.50	29.50
Electric	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hybrid	N/A	N/A	N/A	39.95	43.03	46.16	49.46	52.82	56.26	56.91	57.56	57.85	58.14	58.42	58.71	59.00	59.00
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58.38	59.63	60.89	62.16	63.05	63.95	64.27	64.58	64.90	64.90
AVERAGE	25.86	26.12	26.38	26.73	27.60	28.73	30.58	32.01	34.67	36.08	37.32	38.42	39.45	39.65	39.87	40.07	40.18
MINIVAN FUEL ECONOMY																	
Conventional	22.70	22.88	23.06	23.24	23.42	23.60	23.95	24.29	24.63	24.97	25.31	25.67	26.02	26.38	26.73	27.09	27.09
Advanced Diesel	N/A	N/A	N/A	N/A	33.96	34.23	34.72	35.22	35.71	36.21	36.71	37.22	37.74	38.25	38.76	39.28	39.28
Flex Alcohol	22.70	22.88	23.06	23.24	23.42	23.60	23.95	24.29	24.63	24.97	25.31	25.67	26.02	26.38	26.73	27.09	27.09
SDI	N/A	N/A	N/A	N/A	29.28	29.50	29.93	30.36	30.79	31.22	31.64	32.09	32.53	32.97	33.42	33.86	33.86
CNG Dedicated	N/A	N/A	23.06	23.24	23.42	23.60	23.95	24.29	24.63	24.97	25.31	25.67	26.02	26.38	26.73	27.09	27.09
Electric	N/A	N/A	N/A	N/A	93.69	94.41	95.78	97.15	98.52	99.89	101.26	102.68	104.10	105.52	106.94	108.36	108.36
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	35.94	38.71	41.55	44.45	47.41	47.41
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	55.40	56.14	56.89	56.89
AVERAGE	22.70	22.88	23.06	23.24	23.54	24.05	24.73	25.39	25.81	26.23	26.59	26.90	27.33	27.74	28.29	28.85	28.98
SUV FUEL ECONOMY																	
Conventional	21.10	21.27	21.44	21.60	21.77	21.94	22.26	22.58	22.89	23.21	23.53	23.86	24.19	24.52	24.85	25.18	25.18
Advanced Diesel	0.21	0.21	0.21	0.22	6.49	12.86	19.45	26.23	33.20	33.66	34.12	34.60	35.08	35.55	36.03	36.51	36.51
Flex Alcohol	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDI	N/A	N/A	N/A	N/A	27.22	27.43	27.82	28.22	28.62	29.02	29.41	29.83	30.24	30.65	31.06	31.48	31.48
CNG Dedicated	N/A	N/A	21.44	21.60	21.77	21.94	22.26	22.58	22.89	23.21	23.53	23.86	24.19	24.52	24.85	25.18	25.18
Electric	N/A	N/A	N/A	N/A	87.09	87.76	89.03	90.30	91.58	92.85	94.12	95.44	96.76	98.08	99.40	100.72	100.72
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	33.40	35.98	38.62	41.31	44.07	44.07
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	51.49	52.19	52.88	52.88
AVERAGE	21.10	21.27	21.44	21.60	21.77	22.06	23.08	24.61	26.60	27.96	28.41	27.71	28.81	29.12	31.58	33.50	34.72
PICK-UP AND LARGE VAN FUEL ECONOMY																	
Conventional	19.50	19.64	19.77	19.91	20.04	20.18	20.38	20.58	20.79	20.99	21.19	21.40	21.61	21.83	22.04	22.25	22.25
Advanced Diesel	N/A	N/A	26.69	26.88	27.06	27.24	27.52	27.79	28.06	28.33	28.61	28.89	29.18	29.47	29.75	30.04	30.04
Flex Alcohol	19.50	19.64	19.77	19.91	20.04	20.18	20.38	20.58	20.79	20.99	21.19	21.40	21.61	21.83	22.04	22.25	22.25
SDI	N/A	N/A	N/A	N/A	25.06	25.23	25.48	25.73	25.98	26.24	26.49	26.75	27.02	27.28	27.55	27.81	27.81
CNG Dedicated	19.50	19.64	19.77	19.91	20.04	20.18	20.38	20.58	20.79	20.99	21.19	21.40	21.61	21.83	22.04	22.25	22.25
Electric	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AVERAGE	19.50	19.64	19.81	20.20	20.58	21.05	21.72	22.39	22.88	23.35	23.58	23.82	24.07	24.32	24.56	24.80	24.82

Table A-39 GRPA Technology Utilization Summary

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mb)	Energy Cost Savings (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	0.00	0.00	1.08	0.192	0.13	0.009	0.000	0.2663		0.000			0.001
2001	0.00	0.00	9.21	1.637	0.23	0.135	0.004	0.4297		0.000			0.007
2002	0.00	0.00	22.76	4.046	0.35	0.191	0.012	0.6206		0.000			0.019
2003	0.00	0.00	42.78	7.606	0.49	0.197	0.024	0.8328		0.000			0.037
2004	0.00	0.00	64.70	11.501	0.60	0.151	0.035	1.0408		0.000			0.053
2005	0.00	0.00	89.34	15.882	0.71	-0.021	0.048	1.2430		0.000			0.072
2006	0.00	0.00	112.55	20.008	0.76	-0.109	0.063	1.4065		0.000			0.093
2007	0.00	0.00	132.74	23.598	0.82	-0.219	0.080	1.5327		0.000			0.116
2008	0.00	0.00	150.58	26.769	0.84	-0.333	0.100	1.6414		0.000			0.142
2009	0.00	0.00	166.17	29.540	0.86	-0.438	0.118	1.7358		0.000			0.167
2010	0.00	0.00	179.54	31.918	0.85	-0.536	0.136	1.8176		0.000			0.190
2011	0.00	0.00	189.44	33.676	0.84	-0.642	0.152	1.8770		0.000			0.211
2012	0.00	0.00	196.85	34.994	0.82	-0.718	0.165	1.9230		0.000			0.228
2013	0.00	0.00	201.71	35.858	0.84	-0.788	0.176	1.9551		0.000			0.242
2014	0.00	0.00	204.91	36.426	0.87	-0.835	0.185	1.9768		0.000			0.254
2015	0.00	0.00	205.21	36.480	0.83	-0.888	0.191	1.9817		0.000			0.261
2016	0.00	0.00	204.49	36.353	0.80	-0.908	0.195	1.9795		0.000			0.266
2017	0.00	0.00	203.02	36.091	0.75	-0.919	0.197	1.9744		0.000			0.269
2018	0.00	0.00	201.03	35.737	0.72	-0.922	0.197	1.9669		0.000			0.270
2019	0.00	0.00	198.50	35.287	0.73	-0.911	0.195	1.9563		0.000			0.267
2020	0.00	0.00	195.74	34.797	0.70	-0.891	0.191	1.9437		0.000			0.263
Cumulative Total From Year 2000 to Year													
2005	0.00	0.00	229.87	40.86	2.51	0.66	0.12	4.43	0.00	0.00	0.00	0.00	0.19
2010	0.00	0.00	971.46	172.70	6.64	-0.97	0.62	12.57	0.00	0.00	0.00	0.00	0.90
2015	0.00	0.00	1969.56	350.13	10.84	-4.84	1.49	22.28	0.00	0.00	0.00	0.00	2.09
2020	0.00	0.00	2972.34	528.40	14.54	-9.39	2.47	32.10	0.00	0.00	0.00	0.00	3.43

Table A-40 GRPA Fuels Development Summary

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mb)	Energy Costs (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	0.10	0.00	0.00	0.017	0.000	0.000	0.000	0.0019		0.000			0.000
2001	0.79	0.00	0.00	0.136	-0.001	-0.001	0.000	0.0148		0.000			0.000
2002	2.79	0.00	0.00	0.482	-0.001	-0.003	0.000	0.0526		0.000			0.000
2003	5.39	0.00	0.00	0.929	-0.002	-0.006	0.000	0.1015		0.000			0.000
2004	10.46	0.00	0.00	1.803	-0.004	-0.041	0.046	0.1969		0.002			0.002
2005	54.16	0.00	0.00	9.338	-0.005	-0.118	0.093	1.0198		0.005			0.004
2006	106.52	0.00	0.00	18.366	-0.006	-0.212	0.152	2.0056		0.007			0.006
2007	160.45	0.00	0.00	27.664	-0.007	-0.315	0.220	3.0210		0.011			0.009
2008	214.38	0.00	0.00	36.963	-0.007	-0.418	0.289	4.0364		0.015			0.012
2009	269.84	0.00	0.00	46.523	-0.005	-0.541	0.379	5.0804		0.019			0.017
2010	359.78	0.00	0.00	62.031	-0.001	-0.707	0.478	6.7738		0.025			0.022
2011	449.80	0.00	0.00	77.552	0.003	-0.876	0.579	8.4688		0.030			0.028
2012	540.09	0.00	0.00	93.119	0.010	-1.045	0.678	10.1687		0.036			0.034
2013	635.13	0.00	0.00	109.506	0.024	-1.217	0.772	11.9581		0.041			0.040
2014	736.30	0.00	0.00	126.948	0.052	-1.607	1.024	13.8628		0.047			0.087
2015	787.74	0.00	0.00	135.817	0.070	-1.743	1.128	14.8313		0.054			0.094
2016	834.47	0.00	0.00	143.874	0.076	-1.594	0.988	15.7111		0.053			0.054
2017	870.67	0.00	0.00	150.116	0.063	-1.664	1.031	16.3928		0.056			0.057
2018	913.69	0.00	0.00	157.533	0.065	-1.735	1.065	17.2027		0.058			0.059
2019	958.74	0.00	0.00	165.300	0.073	-1.802	1.091	18.0509		0.059			0.061
2020	1000.64	0.00	0.00	172.524	0.073	-1.859	1.109	18.8397		0.060			0.062
Cumulative Total From Year 2000 to Year													
2005	73.69	0.00	0.00	12.71	-0.01	-0.17	0.14	1.39	0.00	0.01	0.00	0.00	0.01
2010	1184.67	0.00	0.00	204.25	-0.04	-2.36	1.66	22.30	0.00	0.08	0.00	0.00	0.07
2015	4333.73	0.00	0.00	747.19	0.12	-8.85	5.84	81.59	0.00	0.29	0.00	0.00	0.35
2020	8911.94	0.00	0.00	1536.54	0.47	-17.50	11.12	167.79	0.00	0.58	0.00	0.00	0.65

Table A-41 GRPA Advanced Automotive Technologies

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mbpd)	Energy Cost Savings (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	(1) NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	0.00	0.00	0.00	0.517	0.000	0.000	0.000	0.0000		0.000			0.000
2001	0.00	0.00	0.00	0.874	0.000	0.000	0.000	0.0004		0.000			0.000
2002	0.00	0.00	0.00	1.235	-0.003	0.000	0.000	-0.0089		0.000			0.487
2003	3.03	0.03	0.00	3.989	0.005	0.314	0.004	-0.0251		0.000			2.350
2004	28.12	0.26	0.00	10.766	0.229	2.209	0.034	0.3072		0.001			9.851
2005	81.20	0.73	0.00	22.669	0.735	4.504	0.098	1.1069		0.002			23.631
2006	153.97	1.35	0.00	38.074	1.418	5.983	0.190	2.1910		0.005			42.429
2007	249.21	2.19	0.00	57.546	2.345	7.216	0.305	3.6335		0.009			64.986
2008	372.71	3.23	0.00	82.262	3.546	8.668	0.447	5.6184		0.014			90.779
2009	508.33	4.34	0.00	109.244	4.843	9.384	0.618	7.8521		0.021			120.485
2010	637.75	5.47	0.00	135.067	6.110	9.253	0.820	9.9999		0.028			154.820
2011	760.93	6.39	0.00	159.336	7.306	8.991	1.046	12.0979		0.035			193.013
2012	882.53	7.20	0.00	182.885	8.526	9.301	1.294	14.1992		0.042			234.775
2013	997.37	7.86	0.00	204.879	9.773	9.334	1.552	16.2270		0.050			277.888
2014	1109.64	8.42	0.00	226.220	11.025	9.997	1.815	18.2434		0.058			320.650
2015	1214.91	8.88	0.00	246.137	12.028	10.331	2.076	20.1599		0.066			361.410
2016	1310.33	9.22	0.00	264.104	12.998	10.343	2.331	21.9190		0.074			398.385
2017	1394.65	9.48	0.00	279.978	13.667	10.212	2.574	23.4904		0.082			431.532
2018	1468.70	9.65	0.00	293.873	14.411	10.105	2.801	24.8864		0.090			460.485
2019	1532.49	9.76	0.00	305.827	15.162	9.996	3.012	26.1028		0.097			485.187
2020	1589.99	9.82	0.00	316.598	15.713	10.222	3.207	27.1868		0.104			506.971
Cumulative Total From Year 2000 to Year													
2005	112.35	1.02	0.00	40.05	0.97	7.03	0.14	1.38	0.00	0.00	0.00	0.00	36.32
2010	2034.32	17.59	0.00	462.24	19.23	47.53	2.52	30.68	0.00	0.08	0.00	0.00	509.82
2015	6999.71	56.33	0.00	1481.70	67.89	95.48	10.30	111.60	0.00	0.33	0.00	0.00	1897.55
2020	14295.86	104.26	0.00	2942.08	139.84	146.36	24.22	235.19	0.00	0.78	0.00	0.00	4180.11

(1) Assumes diesel meets emission standards

Table A-42 GRPA Advanced Materials

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mb)	Energy Costs (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	(1) NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	0.00	0.00	0.00	0.050	0.000	0.000	0.000	0.0000		0.000			0.000
2001	0.00	0.00	0.00	0.084	0.000	0.000	0.000	0.0000		0.000			0.000
2002	0.00	0.00	0.00	0.119	0.000	0.000	0.000	0.0001		0.000			0.000
2003	0.04	0.00	0.00	0.341	0.001	0.010	0.000	0.0011		0.000			0.000
2004	0.29	0.02	0.00	0.621	0.005	0.068	0.000	0.0065		0.000			0.000
2005	0.76	0.07	0.00	0.968	0.013	0.123	0.001	0.0163		0.000			0.000
2006	1.52	0.13	0.00	1.373	0.025	0.155	0.001	0.0326		0.000			0.000
2007	2.89	0.21	0.00	1.905	0.045	0.203	0.002	0.0615		0.000			0.000
2008	5.34	0.31	0.00	2.658	0.077	0.284	0.004	0.1120		0.001			0.001
2009	8.47	0.42	0.00	3.545	0.117	0.335	0.007	0.1763		0.001			0.001
2010	11.87	0.53	0.00	4.469	0.160	0.342	0.011	0.2463		0.001			0.001
2011	15.52	0.62	0.00	5.391	0.204	0.341	0.016	0.3225		0.001			0.002
2012	19.46	0.69	0.00	6.319	0.250	0.347	0.022	0.4043		0.002			0.002
2013	23.26	0.76	0.00	7.187	0.296	0.341	0.028	0.4840		0.002			0.003
2014	27.39	0.81	0.00	8.091	0.346	0.394	0.036	0.5702		0.003			0.004
2015	31.69	0.86	0.00	9.003	0.393	0.435	0.045	0.6597		0.003			0.004
2016	35.97	0.89	0.00	9.886	0.440	0.456	0.055	0.7463		0.004			0.005
2017	39.89	0.91	0.00	10.692	0.477	0.446	0.066	0.8260		0.005			0.006
2018	43.48	0.93	0.00	11.418	0.515	0.437	0.077	0.8991		0.005			0.007
2019	46.67	0.94	0.00	12.061	0.552	0.426	0.087	0.9645		0.006			0.008
2020	49.66	0.95	0.00	12.659	0.583	0.434	0.098	1.0259		0.007			0.009
Cumulative Total From Year 2000 to Year													
2005	1.09	0.10	0.00	2.2	0.02	0.20	0.00	0.02	0.00	0.00	0.00	0.00	0.00
2010	31.17	1.70	0.00	16.1	0.44	1.52	0.03	0.65	0.00	0.00	0.00	0.00	0.00
2015	148.50	5.44	0.00	52.1	1.93	3.38	0.17	3.09	0.00	0.02	0.00	0.00	0.02
2020	364.16	10.06	0.00	108.8	4.50	5.58	0.56	7.56	0.00	0.04	0.00	0.00	0.05

Table A-43 GRPA Heavy Vehicle Technologies

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mb)	Energy Costs (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	(1) NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	7.47	0.00	2.363	1.289	0.068	0.038	1.666	0.1753		1.554			0.442
2001	13.31	0.00	2.307	2.294	0.121	0.026	3.452	0.3034		3.217			0.917
2002	20.08	0.00	2.154	3.461	0.184	0.010	5.998	0.4432		5.583			1.595
2003	31.25	0.00	1.940	5.388	0.312	-0.007	9.387	0.6607		8.737			2.496
2004	46.19	0.00	1.712	7.963	0.494	0.016	13.587	0.9436		12.678			3.621
2005	64.85	0.00	1.479	11.182	0.735	0.025	18.712	1.2932		17.467			4.992
2006	88.75	0.00	1.305	15.302	1.064	-0.001	24.742	1.7338		22.953			6.607
2007	117.59	0.00	0.979	20.275	1.471	-0.025	31.461	2.2622		29.161			8.417
2008	147.37	0.00	0.731	25.408	1.886	-0.021	38.838	2.8074		35.977			10.419
2009	177.07	0.00	0.584	30.529	2.361	-0.046	46.471	3.3511		43.026			12.505
2010	205.28	0.00	0.436	35.392	2.750	-0.119	54.271	3.8690		50.235			14.661
2011	230.44	0.00	0.336	39.732	3.110	-0.198	61.987	4.3295		57.372			16.820
2012	254.07	0.00	0.259	43.805	3.393	-0.266	69.392	4.7640		64.230			18.925
2013	275.03	0.00	0.207	47.420	3.647	-0.341	76.379	5.1532		70.716			20.947
2014	294.64	0.00	0.170	50.800	3.931	-0.351	82.817	5.5191		76.694			22.846
2015	313.14	0.00	0.139	53.989	4.166	-0.366	88.517	5.8672		82.060			24.602
2016	329.54	0.00	0.115	56.817	4.357	-0.389	93.473	6.1804		86.798			26.209
2017	345.58	0.00	0.000	59.582	4.535	-0.437	97.678	6.4896		90.920			27.675
2018	361.58	0.00	0.000	62.341	4.703	-0.479	101.164	6.8010		94.487			29.022
2019	377.86	0.00	0.000	65.149	4.865	-0.518	104.067	7.1201		97.604			30.278
2020	396.26	0.00	0.000	68.321	5.050	-0.537	106.278	7.4802		100.400			31.512
Cumulative Total From Year 2000 to Year													
2005	183.15	0.00	11.95	31.58	1.91	0.11	52.80	3.82	0.00	49.24	0.00	0.00	14.06
2010	919.21	0.00	15.99	158.48	11.45	-0.10	248.59	17.84	0.00	230.59	0.00	0.00	66.67
2015	2286.53	0.00	17.10	394.23	29.69	-1.62	627.68	43.48	0.00	581.66	0.00	0.00	170.81
2020	4097.35	0.00	17.22	706.44	53.20	-3.98	1130.34	77.55	0.00	1051.87	0.00	0.00	315.51

VSCC Model Structure and Coefficients

The structure of the size class model is based on a three-dimensional matrix of i vehicle technology types and k attributes in each of t years. Each cell C_{ikt} of this matrix contains an attribute value (vehicle or fuel) multiplied by a corresponding coefficient reflecting the potential market share impact of the attribute k on vehicle i in year t. Using a logit function, the model estimates market share an as a function of a technology's attributes, the attributes of competing technologies, and external factors such as fuel prices. This can be expressed as:

$$S_{it} = P_{it} = \sum_{n=1}^{N} \frac{P_{itn}}{N}, \qquad P_{itn} = \frac{e^{V_{itn}}}{\sum_{i=1}^{I} e^{V_{itn}}} \tag{1}$$

where: S_{it} *= market share of vehicle type i in year t*
P_{it} *= aggregate probability over population N of choosing type i in year t*
n *= individual n from population N*
P_{itn} *= probability of individual n choosing type i in year t*
V_{itn} *= a function of the k elements of the vector of attributes (A) and coefficients (B), generally linear in parameters, i.e.:*

$$V = B_1A_1 + B_2A_2 + ... + B_kA_k$$

and V is specific to vehicle i, year t, and individual n.

Vehicle Attribute Coefficients for the QM 2000 Analysis are listed in Exhibit B-1. The VSCC Model estimates the market share penetration of alternative-fuel light vehicles for twelve (12) individual technologies and five (5) vehicle size classes. The twelve vehicle technologies are described as follows: conventional vehicles with internal combustion engines (ICEs) operating on either gasoline or diesel; stratified direct injection engine vehicles operating on gasoline; ICE flex-fuel vehicles operating on a mixture of gasoline and alcohol fuels (ethanol or methanol); ICE dedicated alternative fuel vehicles operating on either alcohol (ethanol or methanol) or gaseous fuels (compressed natural gas or liquid propane gas); hybrid electric vehicles with combustion engines and electric motors operating on either gasoline, diesel, or compressed natural gas; and fuel cell vehicles operating on either gasoline, ethanol, or compressed natural gas. The five vehicle size classes include: small cars (compact and subcompacts, mini-compacts, and 2 seaters), large cars (midsize and large cars), minivans, sport utilities and cargo trucks (pickups and large vans).

Exhibit B-1: Vehicle Attribute Coefficients

Variables	Small Car		Large Car		Sport Utility		Truck & Van		Minivan	
	Coeff.	T-Stat.	Coeff.	T-Stat.	Coeff.	T-Stat.	Coeff.	T-Stat.	Coeff.	T-Stat.
Purchase Price (1,000's of $)	-0.0686	-5.220	-0.0411	-8.542	-0.0350	-3.669	-0.0723	-6.200	-0.1096	-6.287
Dedicated AFV Range (100's of miles)	0.4774	2.149	0.3154	2.336	0.3205	2.184	0.3205	0.000	0.5175	1.929
Maintenance Cost ($ per year)	-0.0004	-2.533	-0.0004	-2.533	-0.0004	-2.533	-0.0004	-2.533	-0.0004	-2.533
Acceleration (seconds)	-0.0646	-2.694	-0.0646	-2.694	-0.0646	-2.694	-0.0646	-2.694	-0.0646	-2.694
Top Speed (miles per hour)	0.0032	1.750	0.0032	1.750	0.0032	1.750	0.0032	1.750	0.0032	1.750
Luggage Space (% of conventional)	0.0035	2.576	0.0035	2.576	0.0035	2.576	0.0035	2.576	0.0035	2.576
Station Fuel Cost ($/mile)	-11.210	-2.824	-8.671	-3.148	-10.843	-4.321	-5.478	-2.597	-10.843	0.000
Home Refueling	0.1138	0.856	0.1138	0.856	0.1138	0.856	0.1138	0.856	0.1138	0.856
Multi-fuel Dummy	-0.5846	-4.170	-0.5846	-4.170	-0.5846	-4.170	-0.5846	-4.170	-0.5846	-4.170
Gasoline Capable Dummy	1.194	3.743	1.194	3.743	1.194	3.743	1.194	3.743	1.194	3.743
Gasoline Range Dummy > 250 miles	0.0034	0.021	0.0034	0.021	0.0034	0.021	0.0034	0.021	0.0034	0.021
Constant Terms										
Gasoline Capable Range > 250 miles	Coeff.	T-Stat.								
Gasoline	-0.33869	-2.157								
Alcohol	-0.08145	0.239								
Dual Gaseous	-0.24143	0.181								
Hybrid	-0.37571	-0.557								
Fuel Availability										
Fuel Availability	2.76	0.000								
Fuel Availability^2	-1.43	0.000								

For each technology, the model considers a set of generic vehicle attributes representative of all vehicles within that technology and a set of fuel attributes corresponding to that technology. The vehicle attributes include:

- Vehicle purchase price in 1996 dollars;
- Vehicle efficiency (on-road) in equivalent miles per gallon of gasoline;
- Annual maintenance cost;
- Acceleration time (seconds from 0 to 30 mph);
- Top speed if lower than ninety (90) miles per hour;
- Range (defined as miles traveled before refueling is required); and
- Luggage space.

The fuel attributes include:

- Fuel price (estimated in dollars per gallon of gasoline equivalent); and
- Fuel availability (defined as the percent of stations offering the fuel for sale).

Consumer derived utilities for vehicle attributes described in the VSCC model were estimated from data collected in a 1995 national stated preference survey (Ref. B-1). The vehicle attribute coefficients and technology constant terms for each size class were derived from analyses using a discrete choice multinomial logit model.

Market penetration estimates for alternative fuel use in multi-fuel and bi-fuel vehicles are represented using a random utility, binomial logit model. This model expresses the value, U, of an option, i, as a function of its attributes and is expressed as:

$$U_{1j} = A_1 + BP_1 + Ce^{b\sigma} + \varepsilon_{1j} \qquad (2)$$

where: *U = total utility*
A = constant term
B = price coefficient
P = fuel price
C = fuel availability coefficient
b = exponential function
σ = *fuel availability.*
ε = *random error that varies across individuals.*

Coefficients used in Equation 2 are listed in Exhibit B-2.

Exhibit B-2: Coefficients Used in Fuel Choice Model for Equation 2

Item	Coefficient	Standard Error
Constant	-0.0503	0.10
Fuel Availability	-3.2651	0.12
Exponent	-5.35	N/A
Fuel Price	-9.1451	0.34

The VSCC model also endogenously estimates alternative fuel availability. This is accomplished through a feedback loop that considers alternative fuel and vehicle purchase. As vehicles capable of using alternative fuels are purchased, potential alternative fuel demand grows. Fuel suppliers are assumed to enter the market when the potential demand achieves a threshold level. In each forecast year the potential demand for each fuel is estimated and checked against available supply. If fuel demand is constrained by available supply, in the following year, additional refueling stations are assumed to open such that the new number of stations becomes sufficient based on last year's demand. As alternative fuel availability increases, the demand for vehicles using these fuels also increases, with respect to vehicle range and fuel price considerations.

The logit function used to estimate alternative fuel market penetration follows the model structure and equations described earlier. Coefficients used in the fuel choice model where developed from two nationwide surveys administered by CARAVAN**7** Opinion Research Corporation during 1996. Equation 2 coefficients were developed by David Greene at Oak Ridge National Laboratory (Ref. B-2).

In regard to attribute coefficient values for vehicles and fuels, it's important to note that a major limitation in estimating the potential household market penetration of alternative vehicle technologies is the lack of *revealed preference data*. Revealed preference data is gathered from actual consumer response in the market place. Currently, there are only a limited number of alternative-fuel technologies commercially available. Although purchase and use data are being collected on these vehicles, they are primarily owned by fleet operators, reflecting the desired attribute utilities of that market.

References for Appendix B

B-1. Thompkins, M. et al., "Determinants of Alternative Fuel Vehicle Choices in the Continental United States," 77th Annual Meeting of the Transportation Research Board, Washington D.C., January 1998.

B-2. Greene, David L. 1997. Survey Evidence on the Importance of Fuel Availability to Choice of Alternative Fuels and Vehicles, Published with permission of the author.

Multipliers for Assessing the Economic Impacts of Investment in Advanced Vehicle Transportation Technologies Based on 1992 Industry Structure and 1995 Regional Data: An Update

Jeffry M. Fang
National Renewable Energy Laboratory

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Advanced vehicle transportation technologies involve bio-fuels, alternative fuels, electric and hybrid vehicles, fuel cells, heavy-duty vehicles, light-duty cars, trucks, and light-weight materials research and development. Investment in such technologies would lead to increases in vehicle costs, improved energy efficiency, and increased use of certain alternative fuels. In addition, there are fuel savings, and changes in consumer consumption expenditures. These changes have direct, indirect, and induced economic impacts on output and employment. In order to assess such impacts, output and employment multipliers are needed.

This note documents the multipliers to be used for making such assessments. It is an update of the September 4, 1998 version, entitled "Multipliers for Assessing the Economic Impacts of Investing in Advanced Transportation Technologies." It covers total output and employment multipliers and their composition, the changes from the 1987 industry structure to the 1992 structure, and some qualifications in the application of the multipliers presented. The appendices present information on the treatment of the bio-fuels industry, the equivalence of the three levels of industry details and aggregation, and the comparison of multipliers based on 1995 and 1992 data, with 1987 industry structure.

1. Total Multipliers for Selected Industries

Table 1 presents the total output and employment multipliers for the U.S. as a whole for those industries needed for computing the economic impacts of investment in research and development in advanced technologies in the automotive industry. These industries include motor vehicles, oil and gas extraction, electric utilities, gas utilities, households, and a sub-group of several industries that are to be used to approximate the production of bio-fuels such as ethanol and bio-diesel. The subgroup consists of farm products, wet corn milling,[1] soybean oil mills, chemical preparations, n.e.c.[2], soap and detergent, and petroleum refining.

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[1] In the September 4, 1998 version of this note, the "forest products" industry (#2 of 38) was used in place of the "wet corn milling" industry. See Appendix A for more details.
[2] The abbreviation "n.e.c." stands for "not elsewhere classified."

Table 1: Final Demand Total Output and Employment Multipliers for Selected Industries

Code	Industry	Final demand Multiplier: Output ($)	Final demand Multiplier: Employment (Jobs/MM$(1995))	Comment
[1]	[2]	[3]	[4]	[5]
#1 of 38	Farm products	3.2411	48.6	High
#14.1700	Wet corn milling*	2.7837	22.7	Low
#14.2500	Soybean oil mills	3.7692	35.8	Medium
#27.0406	Chemical preparations, n.e.c.	3.0139	24.1	High
#29.0201	Soap & detergent	2.8060	19.2	Medium
#31.0101	Petroleum refining	2.5168	11.7	Low
#4 of 38	Oil & gas extraction	2.4222	16.0	
#20 of 38	Motor vehicles	3.3042	25.1	
#68.0100	Electric utilities	2.3254	15.6	
#68.0200	Gas utilities**	2.9904	17.6	
#38 of 38	Households	2.1469	25.6	

Sources: Bureau of Economic Analysis, US Department of Commerce
Regional Input-Output Modeling System (RIMS II),
1992 industry structure, 1995 regional data, U.S. total.

Notes: * This industry replaces #2 of 38, forest products, in the 09/04/99 version.
** Simple average of #68.0201 (natural gas transportation) and #68.0202 (natural gas distribution).

These multipliers are derived from the Regional Input-Output Modeling System (RIMS II) developed by the Bureau of Economic Analysis (BEA), U.S. Department of Commerce. They are based on the 1992 industry structure for the U. S. as a whole and updated with 1995 regional data.

Columns 1 and 2 display the code and the name of the industry used by the BEA. Included are relevant industries from both the 490 detailed 6-digit industries and the 38-industry aggregates. The former is represented by the code of the type #xx.xxxx. The latter is shown with #xx of 38.

Column 3 shows the output multiplier, measuring the total dollar change in output in all industries that will result from a $1 change in output delivered to final demand by the indicated industry. For example, for the motor vehicle industry (#20 of 38), the output multiplier value for final demand is 3.3042, meaning that for each $1 addition to final demand in the motor vehicle industry, the overall direct and indirect impacts on output is $3.3042. Although the multipliers are derived in terms of 1995 dollars, there is no need to convert to 1995 dollars as long as the year-dollar designation is clearly displayed and kept in mind.

Column 4 presents the final demand employment multiplier. It measures the total change in the number of jobs in all industries that result from a $1 million change in output delivered to the final demand by the indicated industry. Since these multipliers are computed using 1995 data, it is necessary, in applying the multipliers, to convert the estimated or forecast values of delivery to final demand from their expressed values to values with constant 1995 dollars.

Column 5 designates the employment impacts of a subgroup of six industries as high, medium, or low relative to those in the group. These six industries are intended to show the feedstock and the refining aspects of the process of manufacturing bio-fuels. Because industries used in RIMS II do not necessarily represent the actual process in bio-fuel production, there is some uncertainty as to the exact multipliers to apply. The refining process has elements similar to that of chemical preparations, n.e.c., soap and detergent, and petroleum refining. In addition, the feedstock may come from farm production, forestry production, and intermediate stage such as wet corn milling, or soybean oil milling. Because of the uncertainty associated with assigning the correct industry, the alternatives of low, medium, and high employment impacts can be used. To be "conservative" in estimating the employment impacts, one can combine the low feedstock impact with low refining impacts; i.e., combining "wet corn milling" with "petroleum refining." To be optimistic in terms of employment impacts, one could combine "farm products" with "chemical preparation, n.e.c." In the middle, one would combine "soybean oil mills" with "soap and detergent." The relative share of feedstock and refining process can be set at 35% and 65%, based on the split in the cost of ethanol production. [3]

2. Composition of Total Employment Multipliers

Application of the total employment multipliers in Column 4 of Table 1 will yield only the total employment that will be generated by the delivery of $1 million (in 1995 dollars) worth of final demand to the particular industry. To obtain the composition of the total employment generated, it is necessary to look into the component multipliers for each of the total employment multipliers included in Table 1. For this purpose, the 38- or 490- industry classifications mentioned above are too complicated and the resulting

[3] See Appendix A for additional discussion of bio-fuels.

values for many industries are likely to have fairly small numbers. Fortunately, BEA also used a classification with the following 11 industry groups:[4]

1	Farm, forestry, and fishery products
2	Mining
3	Construction
4	Durable goods
5	Non-durable goods
6	Transportation and public utilities
7	Wholesale trade
8	Retail trade
9	Finance, insurance, and real estate
10	Service
11	Private households

In such a scheme, these 11 industry groups cover the entire domestic economy. Table 2 presents the component employment multipliers with such industry groupings. Columns 1 and 2 show the numerical designation and names of industry aggregation. Columns 3 through 13 present the detailed component multipliers for those industries included in Table 1. The column headings correspond to those industries shown in Table 1. For example, Column 3 is for the "farm products" sector in the 38-industry classification (#1 of 38). Similarly, Col. 8 is for the petroleum refining industry (#31.0101), one of the 490 detailed component industries.

Each entry in Table 2 represents the additional number of jobs that will occur as a result of $1 million (in 1995 constant dollars) in final demand delivered to the column industry. The "total" row is a simple sum of the 11 industry groups. The values in this row, when rounded, correspond to the total employment multipliers in Table 1.

Similar to the application of total employment multipliers in Table 1, it is necessary to convert "the final demand delivered" to millions of 1995 dollars when applying the multiplier values in Table 2.

3. Composition of the Total Output Multipliers

Table 3 presents the component output multipliers for the total output multipliers shown in Table 1. The format is essentially the same as Table 2 for total employment multipliers except for the total row. In Table 3, the total row represents the sum of only the first 10 industry groups, excluding the "private households" sector. According to the BEA, private households contribute to aggregate output through their earnings. To

[4] For the correspondence among the 11-industry groups, the-38 industry classifications, and the detailed 490 component industries, see Appendix B.

Table 2: Composition of Total Employment Multipliers for Selected Industries
1992 Industry Structure, 1995 Regional Data, US Total

NDIA*	Industry Aggregation	#1 of 38**	#14.1700	#14.2500	#27.0406	#29.0201	#31.0101	#4 of 38	#20 of 38	#68.0100	#68.0200	#38 of 38
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]
1	Farm, forestry, and fishery products*^	29.7902	7.8398	14.4261	1.4283	0.6962	0.3147	0.4139	0.6746	0.4324	0.4567	1.1796
2	Mining	0.1591	0.1973	0.1488	0.4173	0.1679	1.4029	4.2481	0.1564	0.6621	1.8334	0.1142
3	Construction	0.6967	0.6271	0.6834	0.5485	0.4868	0.6788	0.7978	0.5435	1.3534	1.9089	0.5763
4	Durable goods	0.8019	0.5425	0.7473	0.7480	0.6404	0.4204	0.5879	5.8802	0.6322	0.6769	0.8235
5	Non-durable goods	1.8274	2.2816	3.4873	6.0292	4.8421	1.2637	0.6499	2.0586	0.7084	0.7460	1.6604
6	Transportation and public utilities	1.4635	1.4453	1.6208	2.2196	1.3503	0.8760	0.8073	1.4925	3.3888	2.3319	1.2781
7	Wholesale trade	1.6201	1.3269	2.4486	1.2870	1.3462	0.7872	0.5091	1.8070	0.5536	0.6720	1.0128
8	Retail trade	2.2497	1.4897	2.1202	2.1375	1.8204	1.0468	1.2884	2.5029	1.4344	1.5539	4.0532
9	Finance, insurance, & real estate	2.0166	1.5120	2.5733	1.6607	1.4003	0.8865	1.7456	1.6034	1.2450	1.3050	2.6464
10	Service	7.7636	5.3597	7.3810	7.4513	6.3676	3.9166	4.8437	8.1898	5.1198	5.9948	11.9048
11	Private households	0.1757	0.1069	0.1596	0.1588	0.1310	0.0758	0.0966	0.1571	0.1071	0.1123	0.3353
	Total	48.5645	22.7288	35.7964	24.0862	19.2492	11.6694	15.9883	25.066	15.6372	17.5916	25.5846

Source: Bureau of Economic Analysis, U.S. Department of Commerce, RIMS II, 1992 industry structure, 1995 regional data, US total.

Notes:
* NDIA - Numerical designation of industry aggregation.
** The column industries are:

#1 of 38	Farm products	#4 of 38	Oil & gas extraction
#14.1700	Wet corn milling	#20 of 38	Motor vehicles
#14.2500	Soybean oil mills	#68.0100	Electric utilities
#27.0406	Chemical preparations, n.e.c.	#68.0200	Gas utilities (Simple average of #68.0201 (gas transportation) and #68.0202 (gas distribution))
#29.0201	Soap & detergent	#38 of 38	Households
#31.0101	Petroleum refining		

*^ Each entry in this table indicates the number of jobs that will be generated in the row industry for every $1 million in 1995 dollars delivered to column industry.

Table 3: Composition of Total Output Multipliers for Selected Industries
1992 Industry Structure, 1995 Regional Data, US Total

NDIA* [1]	Industry Aggregation [2]	#1 of 38** [3]	#14.1700 [4]	#14.2500 [5]	#27.0406 [6]	#29.0201 [7]	#31.0101 [8]	#4 of 38 [9]	#20 of 38 [10]	#68.0100 [11]	#68.0200 [12]	#38 of 38 [13]
1	Farm, forestry, and fishery products*^	1.3530	0.4025	0.7980	0.0655	0.0338	0.0148	0.0192	0.0316	0.0202	0.0214	0.0546
2	Mining	0.0398	0.0496	0.0379	0.0864	0.0428	0.4040	1.2272	0.0364	0.1582	0.5278	0.0293
3	Construction	0.0491	0.0460	0.0507	0.0403	0.0358	0.0445	0.0562	0.0383	0.0985	0.1328	0.0406
4	Durable goods	0.1263	0.0836	0.1163	0.1270	0.1023	0.0653	0.0956	1.6353	0.0959	0.1047	0.137
5	Non-durable goods	0.4197	1.2411	1.4024	1.4979	1.5967	1.1798	0.1386	0.3552	0.1479	0.1564	0.3263
6	Transportation and public utilities	0.2150	0.2320	0.2397	0.2952	0.1984	0.2554	0.1528	0.2140	1.1962	1.2934	0.2077
7	Wholesale trade	0.1661	0.1361	0.2511	0.1320	0.1381	0.0807	0.0522	0.1853	0.0568	0.0690	0.1039
8	Retail trade	0.0950	0.0629	0.0895	0.0902	0.0768	0.0442	0.0544	0.1056	0.0605	0.0656	0.1711
9	Finance, insurance, & real estate	0.3670	0.2339	0.3841	0.2716	0.2309	0.2100	0.3692	0.2721	0.2085	0.2863	0.4557
10	Service	0.4102	0.2959	0.3993	0.4076	0.3505	0.2182	0.2568	0.4304	0.2825	0.3330	0.6208
11	Private households	0.8422	0.5125	0.7652	0.7615	0.6278	0.3633	0.4629	0.7531	0.5136	0.5381	1.6075
	Total^^	3.2412	2.7836	3.7690	3.0137	2.8061	2.5169	2.4222	3.3042	2.3252	2.9902	2.1470

Source: Bureau of Economic Analysis, U.S. Department of Commerce, RIMS II, 1992 industry structure, 1995 regional data, US total.

Notes:
* NDIA - Numerical designation of industry aggregation.
** The column industries are:

#1 of 38	Farm products	#4 of 38	Oil & gas extraction
#14.1700	Wet corning milling	#20 of 38	Motor vehicles
#14.2500	Soybean oil mills	#68.0100	Electric utilities
#27.0406	Chemical preparations, n.e.c.	#68.0200	Gas utilities (Simple average of natural gas transportation (#68.02010) and natural gas distribution (#68.0202)).
#29.0201	Soap & detergent	#38 of 38	Households
#31.0101	Petroleum refining		

*^ Each entry in this table indicates the additional output that will be generated in the row industry for every $1 of final demand delivered to column industry.
^^ The "Total" row includes only NDIA 1 through 10. The contributions of private households to aggregate output are represented by their earnings.
To avoid double counting, they are not included in the total output multipliers.

include such earnings in the total output multiplier again would represent a double counting.

Note that the values in the "total" row in Table 3 are nearly identical to those of Column 4 of Table 1. The only differences are due to rounding. Each entry in Table 3 represents the dollar change in output that occurs in the row industry for each additional dollar of output delivered to the final demand by the column industry. The multipliers are, in a sense, absolute values and can be applied directly as long as the same year-dollar combination is used.

4. Converting to 1995 Constant Dollars

Given that the employment multipliers in Tables 1 and 2 are derived using constant 1995 dollars, the projected output values need to be converted into 1995 dollars before the multipliers can be applied. Table 4 presents the latest data on implicit GDP price deflators from 1992 through 1997, which can be used for this purpose. For example, if the projected output is in terms of 1997 constant dollars, they need to be deflated by 1.0378.

Table 4. Implicit Gross Domestic Products Price Deflators, 1992-1997

Year	1992=100	1995=100
1992	100.00	93.01
1993	102.64	95.47
1994	105.09	98.50
1995	107.51	100.00
1996	109.53	101.88
1997	111.57	103.78

Source: Bureau of Economic Analysis, Department of Commerce, *Survey of Current Business*, August 1998, Table 3, p. 159.

5. Changes from the 1987 Industry Structure, 1995 Regional Data Version

The current version of RIMS II model is based on 1992 industry structure and 1995 regional data. Several changes from the model using 1987 structure and 1995 data can be noted. First, in conjunction with the switch from 1987 industry structure to 1992 structure, the BEA now uses the standard industrial classification (SIC), rather than the input-output classification of industries. Thus, the number of detailed component industries increases from 471 to 490. For example, the number of industries in the construction sector increases from 5 to 15. The natural gas utility industry is the one industry covered in this note affected by such change. Instead of just one industry for natural gas (#68.0200), it is now composed of two industries, natural gas transportation (#68.0201) and natural gas distribution (#68.0202). However, for our purpose, they are re-combined by using the simple average. Second, the shift of industry structure from the 1987 benchmark to the 1992 benchmark caused a change in the industry used to represent the low employment impacts at the input stage of the bio-fuels production process. "Wet corn milling" (#14.1700) now replaces "forest product" (#2 of 38) as the industry with low employment impact.[5] Third, the magnitude of change in the numeric values of multipliers varies substantially among the industries considered in this note. In terms of total employment multipliers, "wet corning milling" (#14.1700) showed a large decrease (about 27%), while oil & gas extraction and gas utilities increased by approximately 33% and 29%, respectively (Table 5, Column 5). In contrast, the differences in employment multiplier values for other industries such as forest products, soybean oil mills, and household are relatively small. Further, the pattern of changes in the values of output multipliers is similar to that of the employment multipliers (Compare Col. (8) and Col. (5) of Table 5.)

6. Qualifications

When applying the output and employment multipliers to assess the future output and employment impacts from investment in advanced transportation technologies, it is explicitly assumed that the observed past relationship will continue in the future. This assumption derives from the static nature of the input-output analysis, which takes a snap shot of the economy as a whole at a given point of time. However, as can be seen from the comparison between the multipliers from the 1987 structure to the 1992 structure in the previous section, the industry structure does change over time, affecting the values of the multipliers to be applied. Nevertheless, it is still useful to hold the industry structure constant and assess the likely impacts of investing in advanced vehicle transportation technologies.

The multipliers presented in this note are for the total U.S. They should not be used for individual state, economic region, or county. Since the U.S. as a whole represents a much larger enclosed economy than each sub-region, the "leakage" from the system is proportionally much smaller than that of each sub-region. As a result, the US total multipliers are larger than those associated with individual regions. If the focus is on the economic impacts in a specific state or region, multipliers developed specifically for the state or region should be used.

[5] See Appendix A.

References

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Table 5: Comparisons of Employment and Output Multipliers Based on 1987 and 1992 Industry structures (1995 Regional Data)

		Final Demand Employment Multiplier			Final Demand Output Multipliers		
Code	Industry	1987 Structure Jobs/MM95$	1992 Structure Jobs/MM95$	[4]/[3]	1987 Structure $	1992 Structure $	[7]/[6]
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
#1 of 38	Farm products	52.0	48.6	0.935	3.4530	3.2411	0.939
#2 of 38	Forest products	28.4	28.3	0.996	2.8553	2.8317	0.992
#14.1700	Wet corn milling	31	22.7	0.732	3.4637	2.7837	0.804
#14.2500	Soybean oil mills	35.5	35.8	1.008	3.7935	3.7692	0.994
#27.0406	Chemical preparations, n.e.c.	21.6	24.1	1.116	2.9132	3.0139	1.035
#29.0201	Soap & detergent	17.3	19.2	1.110	2.7296	2.8060	1.028
#31.0101	Petroleum refining	10.4	11.7	1.125	2.3475	2.5168	1.072
#4 of 38	Oil & gas extraction	12.0	16.0	1.333	1.9443	2.4222	1.246
#20 of 38	Motor vehicles	24.0	25.1	1.046	3.2388	3.3042	1.020
#68.0100	Electric utilities	14.4	15.6	1.083	2.2404	2.3254	1.038
#68.0200	Gas utilities	13.6	17.6	1.294	2.6559	2.9904	1.126
#38 of 38	Households	25.9	25.6	0.988	2.1796	2.1469	0.985

Appendix A

Considerations of Bio-Fuels

Bio-fuels include mainly bio-ethanol and bio-diesel. The feedstock for producing ethanol may come from corn, switch grass, short rotation woody crops, and agricultural waste such as corn stover, or municipal waste. On the input side, the raw materials come from the farm and the forestry industries. The treatment and refining processes have elements which are somewhat similar to that of petroleum refining, wet corn milling, the milling of cottonseed oil, soybean oil, and vegetable oils, or the process of producing soap and detergents, and some other chemical preparations. In this appendix, the approach to assign multipliers for approximating the production of bio-fuels is explained, using the industry structure for both 1992 and 1987, and 1995 regional data.

1992 Industry Structure, 1995 Data

The RIMS II bio-fuel related industries and their associated multipliers are shown in Table A1. These industries are segregated into two groups. The first group includes the first six, from farm products to vegetable oil mills. These industries can be viewed as the input or feedstock side of process. Looking at the employment multiplier, the high value is the farm products industry with 48.6. The low value is the wet corn milling industry with 22.7. In the middle is the soybean oil mills industry with 35.8. These are labeled with "high," "low," and "medium" respectively. The second group includes chemical preparations, n. e. c., soap & detergent, and petroleum refining. They refer to the refining part of the bio-fuel production process. They are also assigned high, medium, and low ratings based on the magnitude of the employment multiplier.

Table A1. Output and Employment Multipliers for Industries for Bio-fuels (1992 Industry Structure, 1995 Regional Data, U.S.)

Industry Code	Industry	Output Multiplier	Employment Multiplier	Note
#1 of 38	Farm products	3.2411	48.6	High
#2 of 38	Forest products	2.8311	28.3	
14.1700	Wet corn milling	2.7837	22.7	Low
14.2400	Cottonseed oil mills	3.6317	39.4	
14.2500	Soybean oil mills	3.7692	35.8	Medium
14.2600	Vegetable oil mills	3.6966	38.4	
27.0406	Chemical preparations, n.e.c.	3.0139	24.1	High
29.0201	Soap & detergent	2.8060	19.2	Medium
31.0101	Petroleum refining	2.5165	11.7	Low

Since it is not clear which industry grouping in RIMS II correspond most closely to the bio-fuels industry in terms of their economic impacts, it is necessary to approximate it by combining the two stages of production process. To be conservative on the employment impact, the wet corn milling industry can be combined with petroleum refining. On the optimistic side, the farm products industry can be combined with chemical preparation, n.e.c. On the average side, soybean oil mills is paired with soap and detergent industry.

1987 Industry Structure, 1995 Data

Table A2 presents the same type of information as Table A1, except that it is based on 1987 industry structure. The change in the underlying industry structure yielded one major change. The low employment impact industry on the feedstock side now is forest products (#2 of 38), instead of wet corn milling.

Table A2. Output and Employment Multipliers for Industries for Bio-fuels (1987 Industry Structure, 1995 Data)

Industry Code	Industry	Output Multiplier	Employment Multiplier	Note
#1 of 38	Farm products	3.4530	52.0	High
#2 of 38	Forest products	2.8553	28.4	Low
14.1700	Wet corn milling	3.4637	31.0	
14.2400	Cottonseed oil mills	3.9528	45.9	
14.2500	Soybean oil mills	3.7935	35.5	Medium
14.2600	Vegetable oil mills	3.6073	36.8	
27.0406	Chemical preparations, n.e.c.	2.9132	21.6	High
29.0201	Soap & detergent	2.7296	17.3	Medium
31.0101	Petroleum refining	2.3475	10.4	Low

Allocation Factor

What is the division between the feedstock side and the refining side of the bio-fuels production process? Since feedstock is approximately 35% of the cost of ethanol production, a 35% and 65% division is used for this purpose. In application, it is recommended that that these relative shares be applied to the total value of production first to derive the respective production values due to feedstock and due to the refining process. These separate production values are then multiplied with their respective multipliers to generate the output and employment impacts at each stage. They are then summed to derive total output and employment impacts.

Appendix B

Correspondence Among the Three Levels of Industry Aggregation In the RIMS II Model

Numerical designation of industry aggregation	Industry Aggregation	Numerical designation of component detailed industries	Numerical designation of component 38 Industry aggregations
1	Farm & forestry products	1.0100-4.0002	1 - 2
2	Mining	5.000-10.000	3 – 5
3	Construction	11.0101 – 12.0300	6
4	Durable goods	13.0100 –13.0700, 20.0100 – 23.0700, 35.0100 –64.1200	14-23
5	Non-durable goods	14.0101 – 19.0306 24.0100 - 34.0305	7-13
6	Transportation & Public Utilities	65.0100 – 68.0302 78.0100 – 78.0200	24-26
7	Wholesale trade	69.0100	27
8	Retail trade	69.0200	28
9	Finance, insurance, & real estate	70.0100 – 71.0202	29-31
10	Services	72.0101 –77.0900 78.0500-79.0000	32-37
11	Households	91.0000	38

Appendix C

Comparison of Multipliers Based on 1992 and 1995 Data, 1987 Industry Structure

In the main text of this note, RIMS II employment and output multipliers based on 1992 industry structure and 1995 data were presented and compared with those based on 1987 structure and 1995 data. An earlier version of BEA's RIMS II results was based on1987 industry structure and 1992 data. Thus, it is also possible to compare the two sets of multipliers to see if they change to any extent when data from different years are applied to the same industry structure. Tables C1 and C2 present such comparison, respectively, for the output multipliers and for the employment multipliers.

- In general, the changes are fairly minor for the output multipliers. For those industries included in this analysis, the difference is less than 1% (Table C1).

- For the employment multipliers, the changes are largest for sectors such as farm products (19%), soybean oil mills (14%), and forest products (7%). Otherwise the difference are less than 3% (See Table C2).

- The apparent reason for such differences is that there were much larger changes in the earnings/employment ratio in the farm products, forest products, and soybean oil mills industries than in the other industries. Computations show that from 1992 to 1995, the ratio of earnings/employment decreased by 16% for the farm products industry, by 12% for the soybean oil mills industry, and by 6% for the forest products industry. In contrast, the other industries covered in this note have changes that are within + or –3%.

In this comparison, the forest products industry (#2 of 38) is used, instead of the wet corn milling industry (#14.1700) that is used in the main text. As explained in Appendix A, when multipliers from the 1987 structure with 1995 data are considered, the forest products industry is the one with the lowest employment impacts in the input side of the bio-fuel production process.

Table C1: Comparisons of Output Multipliers
Based on 1992 and 1995 Data, and 1987 Industry Structure

		Final Demand Output Multiplier		
Code	Industry	1995 Data ($)	1992 Data ($)	[3]/[4]
[1]	[2]	[3]	[4]	[5]
#1 of 38	Farm products	3.4530	3.4467	1.0018
#2 of 38	Forest products	2.8553	2.8507	1.0016
#14.2500	Soybean oil mills	3.7935	3.7882	1.0014
#27.0406	Chemical preparations, n.e.c.	2.9132	2.9083	1.0017
#29.0201	Soap & detergent	2.7296	2.7256	1.0015
#31.0101	Petroleum refining	2.3475	2.3452	1.0010
#4 of 38	Oil & gas extraction	1.9443	1.9420	1.0012
#20 of 38	Motor vehicles	3.2388	3.2335	1.0016
#68.0100	Electric utilities	2.2404	2.2370	1.0015
#68.0200	Gas utilities	2.6559	2.6527	1.0012
#38 of 38	Households	2.1796	2.1682	1.0053

Table C2: Comparisons of Employment Multipliers
Based on 1992 and 1995 Data, and 1987 Industry Structure

		Final Demand Employment Multiplier			
Code	Industry	1995 Data Jobs/MM95$	1992 Data Jobs/MM92$	1992 Data Jobs/MM95$ [4]/1.0751	[3]/[5]
[1]	[2]	[3]	[4]	[5]	[6]
#1 of 38	Farm products	52.0	46.9	43.6	1.1920
#2 of 38	Forest products	28.4	28.5	26.5	1.0713
#14.2500	Soybean oil mills	35.5	33.4	31.1	1.1427
#27.0406	Chemical preparations, n.e.c.	21.6	23.7	22.0	0.9798
#29.0201	Soap & detergent	17.3	19.0	17.7	0.9789
#31.0101	Petroleum refining	10.4	11.3	10.5	0.9895
#4 of 38	Oil & gas extraction	12.0	13.0	12.1	0.9924
#20 of 38	Motor vehicles	24.0	26.0	24.2	0.9924
#68.0100	Electric utilities	14.4	15.8	14.7	0.9798
#68.0200	Gas utilities	13.6	15.0	14.0	0.9748
#38 of 38	Households	25.9	27.2	25.3	1.0237